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FALCONBRIDGE

PLUME DISPERSION STUDY

May 5 - June 28, 1983

ARB-181-83-AQM

NOVEMBER 1983

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Ministry
of the
Environment

Ontario

The Honourable
Andrew S. Brandt
Minister

Dr. Allan E. Dyer
Deputy Minister

ISBN-0-7743-8944-3

MINISTRY OF THE ENVIRONMENT
AIR RESOURCES BRANCH AND
NORTH EASTERN REGION

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TABLE OF CONTENTS

Page

SECTION 1.0: INTRODUCTION 1

SECTION 2.0: SUMMARY OF FIELD MEASUREMENT PROGRAM 5

2.1 Mobile Monitoring 8
2.2 Minisondes 9
2.3 Doppler Acoustic Sounder 10
2.4 Emissions Measurements 12

SECTION 3.0: SUMMARIES OF SO_2 HALF-HOUR STANDARD AND ONE-HOUR CRITERION EXCEEDANCES MEASURED DURING THE MAY AND JUNE 1983 SURVEY 14

3.1 Case Summaries 14

3.1.1 - May 5, 1983 17
3.1.2 - May 11, 1983 23
3.1.3 - May 13, 1983 28
3.1.4 - May 17, 1983 33
3.1.5 - May 31, 1983 38
3.1.6 - June 9, 1983 43
3.1.7 - June 20, 1983 49
3.1.8 - June 21, 1983 54
3.1.9 - June 24, 1983 59
3.1.10 - June 25, 1983 64
3.1.11 - June 27, 1983 69
3.1.12 - June 28, 1983 75

3.2 Summary of the Observed Exceedances During This Field Study 82

TABLE OF CONTENTS

(cont'd)

Page

SECTION 4.0: PATTERN FOR HIGH GROUND LEVEL CONCENTRATIONS . . . 87

4.1 Introduction 87

4.2 Scenarios for High Ground Level Concentration 89

4.2.1 Light Winds With South-East Component . 89
4.2.2 Light Winds With North-West Component . 89
4.2.3 High Winds 90
4.2.4 Other Conditions 90

4.3 Classification of Field Study Exceedances 91

4.4 Classification of Historical Exceedances 92

SECTION 5.0: FEASIBILITY OF SUPPLEMENTARY CONTROL 95

5.1 Definition 95

5.2 Frequency of High Ground Level Concentration 96

5.3 Feasibility of Modelling High Ground Level Concentrations 97

5.3.1 Morning Trapping (Light winds with south-easterly component) 97
5.3.2 Light Winds With North-westerly Component 100
5.3.3 Windy Conditions 101
5.3.4 Other Controls 101

5.4 Feasibility of Supplementary Control 102

SECTION 6.0: CONCLUSIONS AND RECOMMENDATIONS 105

LIST OF TABLES

Number	Title	Page
1	Falconbridge Study Fixed Location Monitoring Sites	4
2	Falconbridge Study Data Collected	6
3	Field Survey Days When Exceedance of Either the Half-Hour Standard (.3 ppm) or the One-Hour Criterion (.25 ppm) for Ground Level SO_2 Concentrations was Measured	15
4	MAY 5, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	21
5	MAY 5, 1983 - Summary of Boundary Layer Parameters	22
6	MAY 11, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	26
7	MAY 11, 1983 - Summary of Boundary Layer Parameters	27
8	MAY 13, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	31
9	MAY 13, 1983 - Summary of Boundary Layer Parameters	32
10	MAY 17, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	36
11	MAY 17, 1983 - Summary of Boundary Layer Parameters	37
12	MAY 31, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	41
13	MAY 31, 1983 - Summary of Boundary Layer Parameters	42
14 a-b	JUNE 9, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	46-47
15	JUNE 9, 1983 - Summary of Boundary Layer Parameters	48

LIST OF TABLES

(cont'd)

Number	Title	Page
16	JUNE 20, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	52
17	JUNE 20, 1983 - Summary of Boundary Layer Parameters . .	53
18	JUNE 21, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	57
19	JUNE 21, 1983 - Summary of Boundary Layer Parameters . .	58
20	JUNE 24, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	62
21	JUNE 24, 1983 - Summary of Boundary Layer Parameters . .	63
22	JUNE 25, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	67
23	JUNE 25, 1983 - Summary of Boundary Layer Parameters . .	68
24	JUNE 27, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	73
25	JUNE 27, 1983 - Summary of Boundary Layer Parameters . .	74
26 a-b	JUNE 28, 1983 - Acoustic Sounder Half-Hour Average Winds During Periods When Exceedances Were Measured	79-80
27	JUNE 28, 1983 - Summary of Boundary Layer Parameters . .	81
28 a-c	Summary of Emissions, Boundary Layer and Meteorological Parameters Associated with the Record Exceedances During the Falconbridge Field Study (May 5, 1983 - June 28, 1983)	84-86
29	Non-Dimensional Concentration and Down-Wind Distance for Exceedance Meeting the Morning Trapping Criteria and the Well-Mixed Conditions (Calculated According to Equation 5.2)	99

1.0 INTRODUCTION

The analyses of historical air quality data of the Sudbury monitoring network (Kurtz, 1982) revealed that a large number of exceedances of the ground level concentrations of SO_2 can be attributed to the Falconbridge smelter plume. The exceedance here refers either to the excess concentrations over and above Environment Ontario's criterion of .25 ppm for a one-hour average or the excess concentrations over and above the standard of .30 ppm for a half-hour average. It is noted that in the data set analyzed, only the monitors at Skead and Coniston were significantly affected by the Falconbridge plume.

Skead and Coniston are approximately ten kilometers to the north-north-east and south-south-west (respectively) of Falconbridge smelter. (Figure 1 shows the relative location of these monitors and the smelter stack.) The stack through which SO_2 is emitted at Falconbridge is 92 meters high, one-third of which is below the rise on which the smelter is situated. In other words, for winds from the south-east sector the apparent height of the stack above ground is only about 75 meters. If the high ground level concentrations are found to be a consequence of the small stack height at Falconbridge, it is then to be expected that for those cases when Skead and Coniston would register high readings, there might be areas nearer to the stack where the ground level concentrations (glc's) would be even higher.

It would be desirable, therefore, to institute control on the stack emissions in order to eliminate the occurrence of high ground level concentrations attributable to Falconbridge. A supplementary control system which controls the stack emissions only when the dispersion conditions are unfavourable is one option.

A field study was conducted, the objective of which was to investigate typical meteorological conditions during which unfavourable dispersion conditions lead to high ground level concentrations as well as the frequency with which these conditions occur. The infrequent occurrence of these conditions would support the feasibility of instituting a supplementary control system.

The original field study was designed to take place for short periods throughout the year. Due to both the shut-down of the Falconbridge plant during 1982-83 and other limitations, it was not feasible to carry out a field study lasting over one year. A shorter duration study was planned instead, with the hope that a large number of the typical cases which are responsible for the higher concentrations at any time of the year would occur during this specific period.

The field study was conducted during the period from May 5, 1983 to June 28, 1983. Ground level concentrations were measured by three mobile vans equipped with SO_2 monitors and by 12 fixed location SO_2 monitors. The plume was tracked by a correlation spectrometer which gave the SO_2 burden (vertical integration of SO_2 concentrations) as a function of distance along a road. The correlation spectrometer results were used to locate the mobile vans at three sampling positions. Wind speed and direction were measured by the CKSO and CKNC towers in Sudbury and on the meteorological tower in Hanmer. These were supplemented by a doppler acoustic sounder which gave wind speed and direction ranging from 50 to 500 meters in the vertical and a net radiometer which continuously recorded the net radiation at a location approximately three kilometers from the stack. Minisonde flights were carried out each day to provide the vertical temperature and wind field distributions. The synoptic meteorological analyses were carried out daily at Toronto during the study period. Table 1 (page 4) summarizes the locations of the meteorological monitoring sites as well as the locations of the fixed air quality samplers. Site coordinates are reported in Universal Transverse Mercator (UTM) units of tenths of kilometers east and north respectively in Zone 17.

Exceedances of either the half-hour standard or the one-hour criterion or both were measured on 12 days during the study period. From these days a number of these high ground level concentration cases were selected on the basis that their averaging periods did not overlap in time or that their measurement sites were separated in distance by at least one kilometer. Emphasis was given to the half-hour standard; however, if it was not violated, a check was then made to determine whether the one-hour criterion was violated. When both were violated, each constituted a separate case. Defined in this manner, there are 54 measured exceedances.

The sparcity of roads in the Falconbridge area made it difficult to locate monitors at all probable points where violations occurred. It is not to be construed, therefore, that only 54 violations occurred during this period. There might well have been more violations which, due to road limitations, could not be monitored.

This report is an analysis of these 54 cases in order to demonstrate whether or not a supplementary control option is feasible for Falconbridge stacks. In Section 2 the field program is outlined. Section 3 describes the case studies in detail and Section 4 discusses the plausible scenarios where maximum ground level concentrations are expected to occur at Falconbridge. This is all based on our experience with air pollution meteorology at locations with similar topography to that of Falconbridge. Section 5 examines analyses on the feasibility of instituting a supplementary control system and also describes the type of air quality models best suited for this purpose.

TABLE 1

FALCONBRIDGE STUDY FIXED LOCATION MONITORING SITES

	UTM Grid Location	
	East	North
SO_2 Air Concentration Monitors		
Burwash	05144	51228
Callum	05270	51525
Skead	05177	51668
Hanmer	05041	51670
Rayside	04934	51615
Ash St., Sudbury	04994	51486
Coniston	05118	51480
Garson	05109	51559
New Sudbury	05044	51520
Laurentian Hospital	05004	51459
Long Lake	04992	51387
Mikkola	04915	51405
Meteorological Monitors		
Hanmer	05041	51663
CKNC Tower, Sudbury	04995	51505
CKSO Tower, Sudbury (INCO)	04984	51495
Sudbury Airport (YSB)	05155	51634
Field Study Base, MTC Garage, Bailey Corners	05136	51612
Major SO_2 Emission Sources in the Study Region		
Falconbridge	05150	51580
INCO, Copper Cliff (381 meter "superstack")	04957	51471
INCO, Nickel Refinery (formerly (Iron Ore Recovery Plant)	04933	51435

2.0 SUMMARY OF FIELD MEASUREMENT PROGRAM

The air quality emissions and meteorology measurement program began on May 5, 1983 and continued until June 28, 1983. Routine SO_2 ground level concentration measurements at 12 fixed locations in the Falconbridge region (Figure 1) were supplemented by three mobile monitors and a correlation spectrometer (Cospec) to determine the vertically integrated burden of SO_2 from the plume. In-stack monitoring of the smelter emissions was begun by Environment Canada on May 6 and monitoring was continued each day while the mobile SO_2 monitors were in the field.

Routine measurements of winds and temperature at three meteorological towers in the region (Figure 1) and at the Sudbury Airport were supplemented by continuous measurements of net radiation and layer averaged horizontal wind between 50 and 500 meters at 25-meter increments in the vertical. The doppler acoustic sounder measuring layer average winds and the net radiometer were sited at the field study base in the MTC yard at Bailey Corners. Also, each study day a pilot-balloon minisonde system was used for the measure of wind and temperature in the vertical. Mounted on two of the three SO_2 monitoring vans were meteorological instruments measuring wind, temperature, barometric pressure, dew point temperature and solar radiation.

Table 2 (page 6) summarizes the data and information collected during the two-month intensive study. In addition, selected elements of supplementary monitoring programs are described below.

TABLE 2

FALCONBRIDGE STUDY DATA COLLECTED

LOCATION	DESCRIPTION OF DATA	REPORTING FREQUENCY
METEOROLOGICAL		
Sudbury Airport (AES)	- 10 m. winds (3 min. average on hour) - temperature - pressure - relative humidity - precipitation (hrly descript.) (6 hourly amount)	- hourly and 6 hourly
Hanmer 10 m. tower (MOE-NE)	- vector averaged winds	- hourly averages and 5-minute averages
Sudbury MOE tower (MOE-NE)	- winds 10 and 118 m. (vector averages) - temperature at 10 & 118 m.	- hourly averages and 5-minute averages
INCO Tower	- winds 3 and 230 m. - vector averages/temperature 3, 30 and 230 m.	- hourly averages
INCO Radiosonde Data	- instanteous temperature and winds - rise assumed or tracked - X, Y drift of balloon	- 2 or 3 launches daily except when overcast
Acoustic sounder (AES)	- half-hour average winds reported half-hourly from 50 up to 500 meters at 25 meter intervals	- half-hour averages
minisondes (MOE-ARB-NE)	- instanteous temperature and winds - rise assumed or tracked - X, Y drift of balloon	- 1 launch early in day and possible others during day
net radiometer (MOE)	- net radiation Wm^{-2}	- continuous (24 hr) strip chart

Table 2 (cont'd)

ARB Vans MOE-ARB	- UTM location - description of location - time and date - temperature - wind speed and direction - relative humidity - solar radiation - barometric pressure	- 2 vans located by Cospec and visual plume observations - minimum half-hour sampling periods
AIR QUALITY		
Fixed monitors MOE-NE	- SO_2 concentration	- 1-hour or 5-minute average SO_2 concentrations
ARB Vans and NE Van	- SO_2 concentration	- 3 vans located by Cospec and visual plume observations
EMISSIONS		
Falconbridge stack monitor	- emission totals - exit gas temperature - exit velocity - summary of plant activity	- half-hour average measured and half-hour mass balance calculated
INCO 381-stack monitors	- emission totals	- 1-hour average emissions
OTHER PLUME PHOTOS		
MOE Staff (MOE-ARB-NE)	- photos of plume	- irregular
OBSERVER REPORTS		
" "	- observer's notes	- no set schedule
COSPEC		
traverses along roads under plume	- strip charts showing distance travelled and integrated concentration though layer above the monitor	- no set schedule

2.1 MOBILE MONITORING

The field units associated with the Monitoring and Instrumentation Development Unit of the Air Resources Branch during this survey consisted of:

° Mobile Air Monitoring Unit #1 (MAMu#1) is a fully mobile van capable of monitoring six meteorological parameters (wind speed, wind direction, solar radiation, dew point temperature, ambient dry bulb temperature, and barometric pressure) and impingement sulfur dioxide (SO_2) concentrations also referred to as ground level concentrations (glc's). The wind speed and the direction sensors were located atop a 10-meter retractable tower and the gas sampling ports were located approximately 4 meters above ground. MAMu#1 also has the capability of automatic recording upper air (UA) soundings through minisonde releases.

° Mobile Air Monitoring Unit #2 (MAMu#2) Similar to MAMu#1 in design and operation, it has the additional capability of monitoring glc's of ozone, oxides of nitrogen, total hydrocarbons, reduced sulfur compounds and carbon monoxide.

° Mobile Air Monitoring Unit #7 (MAMu#7), also referred to as the Cospec, consisted of a correlation spectrometer together with its power supply, data acquisition system and dedicated mini-computer (HP85) mounted in a sub-compact car. The main purposes of MAMu#7 were the location of the plume, the assurance of no contamination from other sources (i.e. the Inco plumes), the positioning of the other MAMu's under the plume and the determination of the SO_2 optical concentration depths of the plume in the monitoring areas. This spectrometer was an optically dedicated SO_2 analyzer.

° Mobile Air Monitoring Unit #8 (MAMu#8) was the Northeastern Region's mobile laboratory. It monitored only SO_2 concentrations and was operated by personnel from the Regional office under the field direction of the Monitoring and Instrumentation Development Unit for this particular survey. This unit's sampling port was located approximately 3.5 meters above ground.

Prior to the departure of the MAM units from the field base at the MTC garage (UTM coordinates 5135; 51613) near Bailey Corners for the day's monitoring, each unit was calibrated. MAMu's #1 and #2 have built-in permeation tube calibration sources, MAMu#8 has a reference calibrated compressed gas source and MAMu#7 has sealed high/low SO_2 reference cells. MAMu's #1, #2 and #8 used the morning's calibration for the day's work and then recalibrated the following morning. In the field, MAMU#7 calibrated prior to every traverse. These calibrations served two purposes; firstly, they checked the responsivity of the analyzers with respect to specific gases and secondly, they verified the operation of the automated data acquisition system (DAS).

For this two-month survey, 126 monitoring periods were logged by MAMu#1 (42), MAMu#2 (39) and MAMu#8 (45). In addition, there were 91 upper air soundings through the release of minisondes.

2.2 MINISONDES

All upper air (UA) soundings were launched at the MTC garage. Each day commenced with a minisonde release around 700 hours, followed by other releases as the day progressed. On days when there was extensive field monitoring by MAMU's #1, #2, and #8, there was always a final release after the MAMu's returned to the field base.

The minisondes were standard AES pibols (red pilot balloons for cloud height determinations) filled with helium to a calibrated buoyancy (rise rate 3.0 m/sec.) and capable of lifting aloft a temperature sensor and FM transmitter package. The ascent of the minisondes was tracked by theodolites which, in turn, were directly coupled to the MAMu's data acquisition system (DAS). Resistance was measured by the DAS for the azmiuth and elevation and these measurements were directly translated into bearings and height respectively. The minisonde radio report of temperature was monitored by the DAS and recorded every 15 seconds. Monitoring usually terminated after 10 minutes of flight time (equivalent to a minisonde vertical rise of 1800 meters based on the calibrated buoyancy).

The vertical temperature profile is measured relative to the surface temperature. Prior to launching each minisonde, the temperature probe was calibrated with the MAMu#1 or #2 measurement of surface air temperature.

There were 91 minisonde releases during the study period, of which 36 were tracked with double theodolites located along a baseline of known length and 55 were tracked with a single theodolite.

For double theodolite releases, the balloon location may be determined by triangulation. During flights tracked with only a single theodolite, the minisonde height is assumed to be a known function of the balloon rise rate.

2.3 DOPPLER ACOUSTIC SOUNDER

The doppler acoustic sounder was located at the field base at the MTC garage. The instrument used in this study was manufactured in France and was installed, operationally checked and "brought on line" by the Atmospheric Environment Service (AES) of Environment Canada. This instrument was comprised of a mini-computer for automated control and data acquisition, a modem for remote control and data transfer to AES, Downsview, a disc drive unit for data storage, and three transponders with coaxial receivers or microphones.

The acoustic sounder emitted 150 millisecond pulses of monofrequency sound waves from the three transponders and then switched to the sensitive microphones. The time sequence for the transponders and receivers was controlled and set by the mini-computer. The receivers (microphones) were tuned to a specific band width about the singular pulse frequency and they could detect as little as one-millionth of the transmitted power.

The scattered return signal strength was proportional to the temperature inhomogeneities in the acoustic sensing volume; the doppler shifted frequency of the return signal was proportional to the translational velocity of the scatters; and finally the time lapse between the outgoing acoustic pulse and the return signal was directly proportional to the height. Because the three transponders/receivers were oriented at different angles with respect to the vertical and to each other, a three-dimensional wind speed profile was realized through the analysis of the returned frequency field. The return signals and analyzed winds were averaged every half-hour (usually 300 to 900 signals comprised each average), displayed on the CRT of the mini-computer and then were stored on disc for 19 sampling levels during the period from May 5 to June 29, 1983 inclusive.

The doppler acoustic sounder sampling levels were located at 25-meter intervals between 50 and 500 meters. The greater the height, the less likely it is that a significantly strong enough return signal will be detected. There are several periods, therefore, when no winds are reported at the upper levels. In addition, the measurement of vertical wind velocity during this survey was subject to large uncertainties as a result of the sampling procedures; hence, these measurements could not be used and will not be reported in the data tables.

Net Radiation

The instrument used was the CSIOR model CN-1 unit manufactured in Australia and on loan from AES for this particular study. This unit is the standard instrument used by the AES throughout Canada to measure net radiation. AES calibrated the net radiometer "in-house" and verified its responsivity for shortwave radiation (43.9 uV/Wm^2) as well as for longwave radiation (41.7 uV/Wm^2). This instrument measured the difference between the downward electromagnetic flux (mainly incoming solar radiation) and the upward flux from the ground due to longwave radiation and reflection. It was installed 1.8 meter above representative terrain and was maintained following AES's instructions.

A continuous chart recording of the net radiation was taken for the period from May 8, 1983 through June 29, 1983. These charts were subsequently read to determine average net radiation for each hour of the survey period.

2.4 EMISSIONS MEASUREMENTS

An in-stack monitor to collect measurements of smelter stack SO_2 gas concentrations, gas temperature and gas flow rates was operated by the Pollution Measurement Division of Environment Canada. Monitoring of the stack gases was continuous throughout the periods when mobile monitors were in the field except for brief intervals during probe maintenance. The measurements were reduced to half-hour summaries of average gas concentration, flow rate and temperature as well as half-hour total SO_2 emissions which were calculated from the in-stack measurements.

Plant estimates of the SO_2 emissions to stack for each half-hour period between 900 and 1800 hours were based on mass balance calculations given the amount of ore processed, the sulphur content of the ore and plant operations. Plant emissions fluctuate as plant operations change, with the largest half-hour emissions occurring when the gas from the roaster(s) is being sent directly to the stack, by-passing the acid plant and when one or more converters are operating (blowing).

Figure 2 presents a plot of mass balance calculated half-hour emissions in the vertical direction versus in-stack measured half-hour emissions in the horizontal direction.

"One to one" correspondence is shown by the solid dark line. The majority of the data points are clustered about this line, indicating good correlation between the measured and the calculated emissions. Perfect correspondence would result in a correlation coefficient (known as R-squared) of 1.0. For this data set R-squared is 0.7, indicating very good agreement. It can be noted that the mass balance calculation more frequently over-estimates than under-estimates the measured emissions, as indicated by the fact that more data points fall to the left of the "1 to 1" correspondence line than to the right of this line.

The dashed line on Figure 2 indicates the straight line which best fits all of the data. This line has a slope of 0.89 and an intercept on the vertical axis of 0.92 tonnes SO_2/half-hour. This large intercept would suggest that the calculated emission consistently over-estimates the measured emission. This is not true, however, for half-hour emissions greater than 10.0 tonnes in which case the calculated emissions are more likely to under-estimate the measured emissions.

3.0 SUMMARIES OF SO_2 HALF-HOUR STANDARD AND ONE-HOUR CRITERION EXCEEDANCES MEASURED DURING THE MAY AND JUNE 1983 SURVEY

During the months of May and June 1983, supplementary mobile monitoring of the ground level SO_2 concentration occurred on over 50% of the surveyed days. On 12 of these monitoring days at least one exceedance of the ground level concentrations (glc) half-hour standard for SO_2 was reported. In this section only these days will be examined. Table 3 (page 15) summarizes the days to be analyzed and reports both the highest half-hour average glc measured each day as well as the day's total number of recorded exceedances of the half-hour standard and of the one-hour criterion.

Limiting this report to only the 12 days identified in Table 3 does not imply that no other exceedances due to Falconbridge emissions occurred during the months of May and June 1983. In fact, two exceedances were reported at the Skead SO_2 monitor on June 22, 1983 which have not been analyzed in this report due to a lack of supporting meteorological and emissions data. Other exceedances may also have occurred during the study period which were not detected due to limitations on the number and siting of SO_2 ground level concentration monitors.

3.1 CASE SUMMARIES

Summaries of 12 days on which at least one exceedance of the ground level concentration standard for SO_2 was reported are structured in the following manner:

- ° The detected exceedances are tabulated for each case day and the location of the relevant monitor(s) shown.
- ° A synopsis of supplementary air quality and meteorological monitoring procedures is presented for each day, along with abstracts from the plume observer's notes.

TABLE 3

FIELD SURVEY DAYS WHEN EXCEEDANCE OF EITHER THE HALF-HOUR STANDARD (.3 ppm) OR THE ONE-HOUR CRITERION (.25 ppm) FOR GROUND LEVEL SO_2 CONCENTRATIONS WAS MEASURED

Date	Maximum half-hour average glc recorded	Location of Maximum		Total Number Exceedances each	
		Site	(UTM Coordinates) (east, north)	½ hr	1 hr
May 5	.31	Happy Valley	(5148; 51565)	1	0
May 11	.79	South of MTC garage	(5118; 51576)	3	1
May 13	1.14	Skead Monitor	(5177; 51668)	6	3
May 17*	1.03	MTC garage	(5136; 51612)	3	1
May 31	.58	Just east of Airport	(5157; 51627)	3	2
June 9	.58	North of Bailey Corners	(5136; 51624)	5	4
June 20	.43	South of MTC garage	(5117; 51592)	1	0
June 21	.54	Bailey Corners	(5139; 51619)	4	2
June 24	.32	Wahnapitae	(5202; 51502)	1	0
June 25	.44	Coniston Monitor	(5118; 51480)	1	1
June 27	.40	Happy Valley	(5145; 51575)	2	0
June 28	.89	Falconbridge	(5143; 51576)	6	4

Note: Higher half-hour average glc's were recorded by MAMu#2 at approximately the same location while this van sampled from inside the garage using a probe to the outside.

- Plant emissions immediately prior to and during the exceedance period are reviewed.

- An overview of the synoptic (large scale) meteorological conditions occurring each day are presented with the 1000 hours surface weather map.

- The development of the atmospheric boundary layer during each case day is discussed with reference to the exceedance periods.

For clarification, locations and roads in the field study region frequently referred to in the following summaries are shown on the sketch in Figure 3.

A brief overview of the two-month study period is presented following the summaries of the case days.

3.1.1 - May 5, 1983

May 5, 1983 was the first day of the air quality monitoring for the Falconbridge Field Study. During this study day, one exceedance of the half-hour SO_2 concentration standard was recorded by MAMu#1 at a site approximately one kilometer south of the Falconbridge Plant in the area known as Happy Valley. Figure 4 shows the location of the monitor recording this exceedance. Also tabulated on Figure 4 is the measured half-hour average concentration recorded (.30 ppm) during the exceedance period from 1000 to 1030 hours.

Air Quality Monitoring

The SO_2 vertical burden as measured by Cospec was of the order of 70 to 210 ppm-m and the Cospec assured that MAMu#8 was positioned in the centre of the Falconbridge plume where it stayed until 1515. It recorded a SO_2 maximum hourly average concentration (MHAC) of 0.084 ppm and a peak SO_2 glc of 0.124 ppm.

MAMu#1 and #2 were positioned in Happy Valley to obtain SO_2 glc data. Values greater than the SO_2 standard (0.3 ppm for a half-hour average at the point of impingement) were recorded in Happy Valley between 959 and 1034. Peak SO_2 glc was 0.630 ppm. Figure 5 presents a plot of the running half-hour average SO_2 concentration for the half-hour period 1019 through 1042. Also plotted is the half-hour concentration standard. At the top of Figure 5 the meteorological data measured by MAMu#1 is shown. Between 1052 and 1207, SO_2 MHAC of 0.295 ppm and a peak SO_2 glc of 1.095 ppm were recorded. The Cospec positioned MAMu#2 one kilometer east of Wahnapitae on Highway #17 (UTM 5173; 51480) where it stayed gathering data between 1322 and 1402. The SO_2 MHAC acquired at this site was 0.052 ppm and a peak SO_2 glc of 0.105 ppm.

SO_2 glc between 1441 and 1526 at UTM 5171; 51480 were found to be 0.061 ppm MHAC and 0.156 ppm peak.

The fixed location SO_2 air concentration monitoring stations at Coniston, Callum and Garson (all of which are located somewhat to the south of the Falconbridge Plant - see Figure 1) reported no SO_2 concentrations above the monitors' detection limit during the period from 800 to 1600 hours. All other fixed monitors reported zero readings for this day except Burwash and Long Long which may have been influenced by emissions from INCO. Measurements of net radiation and plant SO_2 emissions were not available on this study day.

Emissions

The plant SO_2 emission during the hours from 900 to 1100 were estimated by mass balance calculations. During the first half-hour of this period, 1.7 tonnes of SO_2 were emitted. Two roasters were operating. From 930 to 1030, a converter operated as well and emissions rose to approximately 6.0 tonnes per half-hour. From 1030 to 1100, the converter did not operate but the two roasters continued to be in use, with emissions dropping to 1.7 tonnes. Emissions were not recorded before 900 hours.

Synoptic Meteorology

On the morning of May 5, an arctic cold front moved southward across the region. The front, oriented east to west, crossed the Sudbury district around mid-morning, producing a moderate to brisk northerly flow. By early afternoon, a ridge of high pressure became established over the upper Great Lakes. Skies were mainly cloudy in the morning, with a period of light snowshowers, becoming mainly clear in the afternoon and evening. Northerly winds persisted through the day, with speeds in the range of 15 to 35 km/h in the morning and 10 to 15 km/h in the afternoon. Temperatures remained at or below freezing for most of the morning.

Figure 6 shows the surface weather map for the Sudbury area at 1000 hours. The circles mark the locations of the routine hourly observing stations. The numbers to the left and right of the circle are surface temperatures in degrees (celcius) and coded surface pressure respectively. The amount of shading of the circle is proportional to the cloud cover. The wind's direction is marked by the line extending outward from the circle and the speed (in knots) is indicated by the bars.

Boundary Layer Development

The early morning 715 minisonde temperature profile (Figure 7) showed a stable lapse condition up to approximately 500 meters. Taking the surface temperature T_0 during the period from 1000 to 1100 to be about 273°K, it is seen that the dry adiabatic profile for T_0=273°K intersects the minisonde temperature profile at about 500 meters. We assume, therefore, that the mixed layer height during the period was about 500 meters. (Note that the dry adiabatic profile is defined by a constant decrease in temperature of 9.8°K for each 1,000 meters in height above the surface.)

The acoustic sounder wind profile listed in Table 4 (page 21) shows moderate wind speed and direction shear in the vertical within the lowest 100 meters of the mixed layer.

Although the wind speed shear above 100 meters is not significant, wind direction shear does show marked changes. There appears to be a steep change in the wind direction above 200 meters. The fact that the doppler acoustic sounder data becomes less reliable with height may explain this behaviour of wind direction. Wind direction below 200 meters remains fairly uniform for a given averaging period, but deviates somewhat between the hours.

Table 5 (page 22) presents a summary of boundary layer parameters for May 5, 1983. The average surface temperature was determined by averaging the surface temperatures observed at the Ministry of the Environment Meteorological tower in Sudbury, the INCO meteorological tower in Sudbury and at the Sudbury airport. This data was used to define the surface temperature for the early morning minisonde launch after it was found that the morning launch surface temperatures reported by MAMu#1 and MAMu#2 were incorrect. As a result, the horizontal axis in Figure 7 (and in subsequent temperature profile plots) is shifted and the corrected temperature is entered as the second row of numbers beneath the interval marks. Figure 7 and the average surface temperature are used to estimate the mixed layer (boundary layer) height. Because no heat flux measurements are available, the other parameters (e.g. the convective velocity scale, W*) could not be estimated.

TABLE 4

MAY 5, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	930-1000		1000-1030	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	4.5	39.	5.2	6.
75	5.4	35.	6.0	13.
100	4.3	33.	7.5	8.
125	6.2	50.	7.0	6.
150	4.4	52.	-	-
175	6.6	49.	7.0	321.
200	6.1	38.	-	-
225	6.9	51.	3.1	288.
250	6.7	49.	-	-
275	8.6	37.	-	-
300	-	-	9.2	7.
325	4.8	75.	-	-
350	5.1	106.	3.8	28.
375	3.3	92.	-	-
400	-	-	-	-
425	-	-	.0	0.
450	-	-	.0	0.
475	-	-	.0	0.
500	-	-	.0	0.

TABLE 5

MAY 5, 1983

SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	273	not measured	500	insufficient data available to calculate
0600-0700	273		500	
0700-0800	272		500	
0800-0900	272		500	
0900-1000	273		500	
1000-1100	273		500	
1100-1200	274		500	
1200-1300	274		500	
1300-1400	276		750	
1400-1500	278		825	
1500-1600	279		925	
1600-1700	280		1250	
1700-1800	280		1250	
1800-1900	281		1350	
1900-2000	281		1350	

3.1.2 - May 11, 1983

Exceedances of the half-hour SO_2 ground level concentration standard were reported by MAMu#2 when located approximately 3 kilometers north-west of the Falconbridge Plant during the three consecutive half-hour periods from 955 to 1125. The one-hour criterion for ground level SO_2 concentration was also exceeded between 1000 and 1100 hours. Figure 8 shows the location of MAMu#2 with respect to the Plant as well as the measured half-hour and one-hour average concentrations during the exceedance periods.

Air Quality Monitoring

Exceedances above the SO_2 standard were recorded between 945 and 1125 at UTM 5120; 51596. The SO_2 MHAC was 0.789 ppm and the peak SO_2 glc was 1.587 ppm. Figure 9 shows a plot of the half-hour average SO_2 concentrations measured for half-hour periods ending between 1013 and 1117. Also plotted is the half-hour standard of .3 ppm.

At the fixed location SO_2 monitor at Hanmer (14 kilometers north-west of Falconbridge), early morning half-hour average SO_2 concentrations were typically between .01 and .07 ppm during the period from 800 to 1200. After 1200, the average hourly concentration rose to .14 ppm from 1200 to 1230 and from 1230 to 1300 and to .11 ppm from 1300 to 1330, after which the average concentrations reduced to less than .04 ppm. The other fixed monitors throughout the study region reported average SO_2 concentrations typically .02 ppm or less, except at Garson and Skead where the average concentrations for the hour 1100 to 1200 were .05 and .03 ppm respectively.

Emissions

Emissions were calculated to be approximately 5.5 tonnes per half-hour from 900 to 1030. Two roasters were operating plus a converter. The emissions fell to 4.0 tonnes between 1030 and 1100 when the converter operated only 16 minutes. From 1100 to 1130, only the roasters were operating and emissions were calculated to be 1.5 tonnes and were measured to be 2.0 tonnes. Measurement of stack emissions did not begin until 1100 hours.

Synoptic Meteorology

The weather in the Sudbury area was dominated by a broad ridge of high pressure which covered the Great Lakes throughout the day. The pressure gradients remained weak and, as a consequence, the air flow was light and variable. Skies were mainly clear and temperatures ranged from an early morning low of 3°C to an afternoon maximum of 20°C. Calm conditions prevailed for most of the morning, becoming southerly by afternoon, with speeds in the range of 5 to 10 km/h.

At around 1000, local weather conditions could be described as sunny (1/10th cloud amount) and near calm winds. There was weak surface flow from the south to south-south-east at less than 3 km/h. Figure 10 shows the surface weather map for 1000 hours.

Boundary Layer Development

The mixed layer height estimated from the minisonde temperature profile and surface temperature increased from 50 meters at 600 hours to a maximum value at 1600 hours. The mixed layer height during the period of interest (900 to 1100 hours) ranged from 150 to 500 meters. The mixed layer was fairly unsteady during the period from 600 to 1300, showing rapid rise of its height. The early morning (753 hours) temperature profile (presented in Figure 11) shows a strong low level nocturnal temperature inversion below 150 meters.

The mixed layer wind speed at all levels during the period from 1000 to 1130 was light, of the order of 2 to 3 ms^{-1} and the direction was highly variable.

After having a value of 1.3 ms^{-1} during the period from 1000 to 1100, the mixed layer velocity scale W* (a measure of the vertical mixing in the boundary layer due to positive heat flux at the surface) reached a peak value of 2.0 ms^{-1} at 1400. The ratio of the mean horizontal wind speed (V) to W* may be used to test whether the boundary layer is convective (very unstable) as well as whether fumigation of elevated plumes may be expected. During the periods from 1000 to 1100 and 1100 to 1200, V/W* was between approximately 2 and 4, indicating that the boundary layer was convective. Table 7 (page 27) summarizes the boundary layer parameters this day.

TABLE 6

MAY 11, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1000-1030		1030-1100		1100-1130	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	.0	0.	2.1	171.	.8	16.
75	.0	0.	2.4	151.	2.4	328.
100	.0	0.	2.6	179.	2.4	330.
125	.0	0.	2.1	200.	4.3	302.
150	.0	0.	3.0	199.	3.8	284.
175	.0	0.	.0	0.	3.9	280.
200	.0	0.	6.2	175.	3.1	297.
225	.0	0.	5.8	178.	2.7	313.
250	.0	0.	6.8	170.	2.9	293.
275	.0	0.	.0	0.	3.0	296.
300	.0	0.	7.3	174.	2.8	291.
325	.0	0.	6.7	170.	1.4	273.
350	.0	0.	.0	0.	1.7	299.
375	.0	0.	8.3	156.	1.4	134.
400	.0	0.	8.5	162.	1.4	313.
425	.0	0.	.0	0.	.8	222.
450	.0	0.	9.6	131.	1.8	270.
475	.0	0.	.0	0.	2.8	185.
500	.0	0.	.0	0.	.0	0.

TABLE 7
MAY 11, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface+ Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	278	-.013	50	NC*
0600-0700	278	-.003	50	NC
0700-0800	280	.018	50	.3
0800-0900	282	.052	75	.5
0900-1000	284	.084	150	.8
1000-1100	286	.115	500	1.3
1100-1200	287	.138	800	1.6
1200-1300	288	.152	850	1.7
1300-1400	290	.155	1175	2.0
1400-1500	291	.149	1250	2.0
1500-1600	292	-	1350	-
1600-1700	293	.109	1450	1.9
1700-1800	293	.073	1450	1.7
1800-1900	292	.034	1350	1.2
1900-2000	291	-.001	1250	NC

+ surface heat flux assumed proportional to .4 times the measured net radiation

* NC - not convective

3.1.3 - May 13, 1983

Exceedances of the half-hour standard for SO_2 were measured by MAMu#8 at the Skead fixed monitor, approximately 10 kilometers north-north-east of the Plant at Bolands Bay and near the Sudbury Airport approximately five kilometers north of the Plant by MAMu#1. In total, six separate exceedances of the half-hour standard were observed (four at Skead and one by each of the mobile monitors). The one-hour criterion of .25 ppm was exceeded between 900 and 1100 hours at Skead and between 1000 and 1100 hours at Bolands Bay by MAMu#8. Figure 12 shows the locations of the monitors reporting exceedances and presents a table of the corresponding average SO_2 concentrations.

Air Quality Monitoring

The largest exceedances of both the half-hour and the one-hour average SO_2 concentrations were reported at the Skead fixed monitor for the periods from 1000 to 1035 through 1130 to 1200 (half-hour standard) and from 940 to 1040 through 1125 to 1225 (one-hour criterion). After 1100, measured SO_2 concentrations (not averaged) dropped to approximately .01 ppm. Figure 13 shows the half-hour average SO_2 concentration measured at the fixed Skead monitor and plotted as a function of the time the averaging period ends. Other fixed monitors in the study did not report average concentrations greater than .02 ppm during the period of the exceedance at Skead. After 1220, measured SO_2 concentrations at Skead and Hanmer increased to typical values between .10 and .15 ppm and remained elevated into the mid-afternoon.

Figure 14 shows the half-hour average SO_2 concentration observed by MAMu#8 located at UTM 5182; 51662. MAMu#1 set up at the Sudbury Airport at 1111 and remained until 1237. It measured 0.48 ppm for MHAC and 1.07 ppm peak SO_2 glc. Figure 15 presents the half-hour SO_2 glc's observed by MAMu#1. Because of the high SO_2 glc's experienced in the Bolands Bay area, the Regional Office of the MOE requested Falconbridge to reduce their emissions at 1040. The Cospec for this day was used only to site the MAM units since, due to road availability, it could only travel parallel to the plume direction.

Emissions

Both roasters were operating during the period of the exceedances and roaster #2 was feeding directly to the stack most of the time between 900 and 1100. With no converter operating from 900 to 930, measured emissions were 7.8 tonnes SO_2. From 930 to 1000, emissions rose to 11.8 tonnes (with one converter operating for 30 minutes) and from 1000 to 1030, the emission rate was 10.4 tonnes (with the converter in use for 28 minutes). From 1030 to 1130, the converter operated for just one minute and emissions were approximately 4.8 tonnes per half-hour. No measurement of emissions was available for this half-hour. From 1130 to 1200 emissions were 3.3 tonnes, with the converter running for 15 minutes but with roaster #1 feeding directly to the stack for 20 minutes.

Synoptic Meteorology

The synoptic situation for the morning of May 13 consisted of a broad ridge of high pressure extending southward from James Bay through the lower Great Lakes area. This ridge dominated the area for most of the day. In the Sudbury region, just west of the ridge centre, calm conditions prevailed until around 800 hours, at which time a light southerly flow became established. By late afternoon, moderate southerly winds prevailed. Skies were mainly clear and temperatures ranged from a morning minimum of 9°C to an afternoon maximum of 23°C. Surface winds ranged from calm to about 5 to 10 km/h by late morning and between 10 and 20 km/h in the afternoon. Figure 16 presents the 1000 hours surface weather map. At this time, skies in the Sudbury area were generally clear and the surface flow was from the south to south-south-west within speeds ranging from 6 to 8 km/h.

Boundary Layer Development

The mixed layer height estimated from minisonde temperature profile (Figure 17) and surface temperature increased from about 50 meters in the early morning to 400 meters at 1300. It remained steady at 400 meters up to 1800 hours. The mixed layer height during the period of the exceedances was between 75 and 170 meters.

The mixed layer average wind speed varied between approximately 2.5 and 6.0 ms^{-1}, as measured by the acoustic sounder (Table 8 - page 31). Although there appears to be a marked change in wind direction at 100 meters during the period from 900 to 930, no such change is evident from 930 to 1200. This may not, therefore, be a true measurement of the direction. The wind direction otherwise changed by only about 10° within the mixed layer.

The convective velocity scale, W*, was calculated to have had a peak value of 1.3 ms^{-1} at 1300. During the period of interest, W* varied between .6 ms^{-1} and 1.0 ms^{-1}. Thus V/W* varied between 4 and 6, indicating that the turbulence in the boundary layer did have a strong convective component. Table 9 (page 32) summarizes the boundary layer parameters for May 13, 1983.

TABLE 8

MAY 13, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	900-930		930-1000		1000-1030		1030-1100		1130-1200	
H	U BAR	DIR	U BAR	DIR	U BAR	DIR	U BAR	DIR	U BAR	DIR
(M)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)
50	2.2	180.	2.6	177.	3.2	191.	3.0	200.	2.8	187.
75	2.5	185.	2.7	181.	3.9	185.	5.5	194.	3.6	195.
100	2.6	215.	4.4	187.	4.0	204.	5.9	192.	3.1	208.
125	2.4	137.	3.2	190.	3.5	179.	6.5	172.	4.1	197.
150	---	---	3.8	186.	3.4	197.	---	---	3.1	213.
175	3.7	214.	4.1	192.	3.5	178.	4.8	187.	2.6	201.
200	3.5	200.	4.2	183.	4.9	154.	4.4	211.	1.2	206.
225	4.4	205.	4.9	185.	5.8	165.	3.6	214.	2.2	206.
250	5.3	188.	4.4	182.	5.5	193.	3.3	208.	1.6	286.
275	4.5	194.	5.5	180.	4.4	189.	2.5	207.	2.2	197.
300	.0	0.	5.8	179.	---	---	2.6	221.	2.6	175.
325	6.4	188.	6.5	179.	5.6	188.	---	---	5.3	173.
350	7.6	183.	6.1	179.	5.7	186.	.0	0.	.0	0.
375	7.5	184.	6.3	182.	6.8	181.	2.3	228.	2.9	143.
400	7.6	179.	5.0	180.	6.5	182.	.0	0.	3.0	200.
425	7.6	181.	7.1	178.	6.6	176.	2.5	214.	.0	0.
450	.0	0.	6.5	172.	7.2	176.	2.1	233.	.0	0.
475	.0	0.	.0	0.	6.8	179.	3.8	191.	4.3	197.
500	8.0	163.	10.3	167.	5.4	172.	2.0	246.	.0	0.

TABLE 9
MAY 13, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	282	-.011	< 50	NC
0600-0700	283	-.006	< 50	NC
0700-0800	285	.018	< 50	.3
0800-0900	286	.057	< 50	.4
0900-1000	287	.088	75	.6
1000-1100	290	.118	100	.7
1100-1200	292	.144	170	1.0
1200-1300	293	.154	275	1.1
1300-1400	294	.162	400	1.3
1400-1500	295	.156	400	1.3
1500-1600	295	.145	400	1.3
1600-1700	295	.107	400	1.2
1700-1800	295	.051	400	.9
1800-1900	294	.044	400	.9
1900-2000	293	.010	170	.4

3.1.4 - May 17, 1983

Three separate exceedances of the half-hour ground level concentration standard for SO_2 were recorded on this day at the MTC garage approximately 3.5 kilometers north and west of the Plant. Also during this period there was an exceedance of the one-hour SO_2 glc criterion at this site. Figure 18 shows the location for the MTC garage (which was also the Field study base) relative to the Falconbridge Plant. Tabulated on Figure 18 are the average SO_2 concentrations recorded during the exceedance periods at this site.

Air Quality Monitoring

MAMu#8 commenced acquiring SO_2 glc data at the MTC garage at 745. Fumigation had started around 800 at the MTC garage area. For the period from 755 to 850, SO_2 half-hour average glc's were in excess of the SO_2 standard (Figure 19); with MHAC being 0.993 ppm and peak glc being 0.997 ppm. The Cospec was sent out at 845 toward CFB Falconbridge and the Capreol Lake Road. MAMu#8 moved to location UTM 5092; 51729 and started acquiring data at 950.

Between 845 and 900, MAMu#7 (Cospec) recorded vertical SO_2 burden of 1300 ppm-m in the garage area. When moved over to the Capreol Lake Road area just before 1000, it was picking up SO_2 signals in the range of 465 ppm-m.

MAMu#1 and #2 both monitored at the MTC garage during the first part of the morning. Between 833 and 939, MAMu#1 recorded exceedances above the standard for this complete period, with a SO_2 MHAC of 1.025 ppm and a peak SO_2 glc of 1.175 ppm. Figure 20 presents the running half-hour average SO_2 concentrations measured by MAMu#1. MAMu#2 was monitoring through a sampling probe run from the inside of the garage to the leeward outside. Between 823 and 1018, MAMu#2 recorded exceedances above the SO_2 standard for this complete period, with a SO_2 MHAC of 2.768 ppm and a peak SO_2 glc of 4.317 ppm.

At 1025, MAMu#7 detected the Falconbridge plume over CFB Falconbridge and MAMu#2 moved over to this site. The Cospec's signal at this site was of the order of 510 ppm-m.

At the fixed location, SO_2 monitors in the study region reported no concentrations greater than .01 ppm until 1030 when Garson (4.5 kilometers west-south-west of the Falconbridge Plant) and Hanmer (14 kilometers north-west of the Plant) reported slight increases. Despite these increases, half-hour average concentration remained less than .03 ppm. In the late afternoon (1700), some fixed monitors recorded somewhat higher concentrations (e.g. .16 ppm at New Sudbury) although no exceedance was observed.

Emissions

Prior to 900 hours, emissions were not measured or calculated. From 900 to 930, they were measured to be 10.9 tonnes. One roaster was operating with venting directly to the stack, in addition to 18 minutes of one converter. From 930 to 1000, emissions of 6.5 tonnes resulted from one roaster and 30 minutes operation of one converter.

Synoptic Meteorology

On May 17, the weather in the Sudbury area was dominated by a quasi-stationary high pressure system centred over the Great Lakes. With the associated weak pressure gradients, the airflow was generally very light and variable. Mainly sunny skies prevailed and temperatures ranged from a morning minimum of -1°C to an afternoon maximum of 11°C. Surface winds in the Sudbury area were initially calm, becoming mainly south-east 5 km/h by mid-morning. Figure 21 shows the surface weather map for 1000 hours. In the afternoon, winds veered to the south-south-west, with speeds in the range of 5 to 10 km/h.

On this day, the highest SO_2 reading was noted around 830. The prevailing local weather was sunny conditions (1/10th sky cover), with surface winds from the south to south-east at 4 to 5 km/h.

Boundary Layer Development

The mixed layer height estimated from minisonde temperature* profile (Figure 22) increased from about 50 meters at 600 hours to 2,200 meters at 1400 hours. During the period from 800 to 1000, it increased from 300 meters to 800 meters and the weak nocturnal inversion observed during the 711 UA sounding dissipated. A second minisonde released at 959 showed that the inversion had completely dissipated.

Wind speed and direction presented in Table 10 (page 36) are available only after 830 hours. For the period from 830 to 930, the wind speed was about 2 to 4 ms^{-1} within the mixed layer and the average mixed layer wind speed was about 4 ms^{-1}.

The convective velocity scale, W*, had a peak value of 2.5 ms^{-1} at 1500 hours. During the period from 800 to 1000, W* varied from 0.5 to 1.4 ms^{-1}. Thus V/W* varied between 2.5 and 8.0 and the boundary layer may be assumed to be convective during this period. Table 11 (page 37) presents boundary layer parameters for this day.

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* The surface temperatures reported at the site of minisonde flights were generally higher than those reported elsewhere in the Sudbury area. A correction has been applied to the surface temperature based on the average surface temperature in the Sudbury area. The magnitude of this correction is a function of the time of the day.

TABLE 10

MAY 17, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	830-900		900-930	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	1.9	146.	.0	0.
75	3.3	140.	.0	0.
100	3.3	164.	2.8	208.
125	3.7	139.	2.8	202.
150	3.3	139.	3.2	178.
175	3.0	136.	2.5	173.
200	3.2	139.	2.5	179.
225	4.2	148.	2.3	142.
250	4.3	139.	3.6	169.
275	6.6	118.	1.8	193.
300	7.5	112.	2.7	170.
325	---	---.	1.0	221.
350	3.4	138.	.0	0.
375	2.4	149.	.6	17.
400	.0	0.	.0	0.
425	6.7	92.	.0	0.
450	.0	0.	.0	0.
475	2.1	94.	9.9	127.
500	.0	0.	.0	0.

TABLE 11
MAY 17, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	274	-.016	< 50	NC
0600-0700	274	-.007	< 50	NC
0700-0800	274	.016	< 50	.3
0800-0900	277	.049	300	.5
0900-1000	279	.085	800	1.4
1000-1100	280	.102	1000	1.6
1100-1200	280	.039	1000	1.2
1200-1300	281	.039	1500	1.4
1300-1400	282	.062	1900	1.8
1400-1500	283	.121	2200	2.5
1500-1600	283	.127	> 2200	2.5
1600-1700	283	.105	> 2200	2.4
1700-1800	284	.056	> 2200	1.9
1800-1900	284	.042	> 2200	1.7
1900-2000	283	.001	> 2200	.5

3.1.5 - May 31, 1983

On this day three separate exceedances of the half-hour SO_2 ground level concentration standard were recorded along the Airport Road just east of Bailey Corners, approximately five kilometers north of the Falconbridge Plant. Two exceedances of the one-hour criterion were also measured. Figure 23 shows the locations of MAMu#1 and MAMu#8 while monitoring the exceedances. The average concentrations measured during the exceedance periods are also noted on Figure 23.

Air Quality Monitoring

MAMu#7 positioned MAMu#2 at the Airport Pit entrance on Airport Road at 1035 and MAMu#8 at Bailey Corners (700 meters west of MAMu#2) at 1027. MAMu#7 made traverses along the Airport Road for the remainder of the day and accumulated 16 traverses, of which runs #1 to 3 and #11 to 16 were recorded on strip chart only and runs #4 to 10 were computer logged. Maximum Cospec readings were in the 200 to 600 ppm-m range. Figure 24 presents a time series of Cospec profiles measured between sites A & B shown on the accompanying map. The numbers 1, 2, & 8 on the horizontal axis note the positions of the mobile monitors along the profile.

A minisonde was released at 1040 at the MTC garage. MAMu#8 located at Bailey Corners until 1125 and recorded SO_2 glc's in excess of 0.3 ppm for the period from 1025 to 1105, with a MHAC of 0.372 ppm and a peak concentration of 0.601 ppm. Figure 25 shows the half-hour average concentrations measured by MAMu#8. MAMu#2 remained at the Airport Pit entrance until 1353 when it terminated its survey for the day. At this site, MAMu#2 obtained a MHAC of 0.04 ppm SO_2 and a peak SO_2 glc of 0.25 ppm.

Figure 26 depicts MAMu#1's monitoring results at the Sudbury Airport entrance. MAMu#8 moved from Bailey Corners to 1.5 kilometers east of the Sudbury Airport (5167; 51618). Between 1315 and 1345, MAMu#8 recorded a SO_2 MHAC of 0.478 ppm, with a peak SO_2 glc of 1.480 ppm.

The only fixed monitors reporting SO_2 concentrations greater than .01 ppm during the morning and early afternoon on May 31 were Rayside and Skead. Rayside is located approximately 14 kilometers north of the INCO (Copper Cliff) 381-meter stack and 22 kilometers east of the Falconbridge stacks. Concentrations at this monitor fluctuated between .01 and .12 ppm during most of the period under consideration. At Skead, 10 kilometers north-east of the Falconbridge Plant, the concentration began to increase after 1200. Between 1200 and 1400, the half-hour average SO_2 concentrations were between .08 and .16 ppm.

Emissions

Both roasters operated during the period from 1000 to 1400 hours. In addition, one converter operated for more than 22 minutes of each half-hour except for 12 minutes from 1100 to 1130 and 8 minutes from 1200 to 1230. With full operation of the roasters and converter, emissions were measured to be approximately 6.0 tonnes SO_2 per half-hour. In the half-hour periods with low utilization of the converter, emissions fell to as low as 2.6 tonnes per half-hour.

Synoptic Meteorology

On May 31, the Sudbury area was under the influence of a quasi-stationary low pressure system centred over the upper Great Lakes near Sault Ste. Marie. As a result, the region was dominated by south to south-easterly flows. Skies remained cloudy to overcast throughout the day, with scattered rainshowers in the afternoon, evening and night. Temperatures ranged from 7°C in the morning to 12°C in the afternoon and wind speeds were in the general range of 5 to 15 km/h. Figure 27 presents the 1000 hours surface weather map for this day.

Boundary Layer Development

The mixed layer height estimated from minisonde temperature profile (Figure 28) and surface temperature increased from 50 meters in the early morning to 630 meters at 1700. During the period from 1200 to 1500, it remained fairly steady at 450 meters while between 1000 and 1200 hours it varied in height between 150 and 360 meters due to the cloudiness.

The mixed layer wind speeds from 1030 to 1200 (Table 12 - page 41) were light, of the order of 2 to $3ms^{-1}$, with no significant vertical shear. The wind direction, however, showed marked variability, especially at higher levels. Once again this could be attributed to acoustic radar resolution, although the turbulence due to the underlying topography cannot be completely ruled out. Between 1230 and 1400, the mixed layer wind speeds were on the order of 3 to 4 ms^{-1} and, again, the direction showed marked variation.

The convective velocity scale, W*, during the period from 1000 to 1400 varied between 0.6 and $1.3ms^{-1}$. Thus V/W* varied between 2 and 6, showing a shallow convective boundary layer. Table 13 (page 42) presents a summary of the boundary layer parameters.

TABLE 12

MAY 31, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1030-1100		1100-1130		1230-1300		1300-1330		1330-1400	
H	U BAR	DIR	U BAR	DIR	U BAR	DIR	U BAR	DIR	U BAR	DIR
M)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)
50	2.0	179.	1.6	182.	---	---	2.2	196.	1.1	241.
75	2.7	195.	2.6	215.	3.0	221.	3.2	217.	2.6	251.
100	2.4	179.	2.4	199.	2.3	214.	3.6	220.	3.1	253.
125	2.3	170.	2.2	194.	2.9	224.	4.0	228.	3.5	265.
150	2.4	133.	1.8	199.	3.3	228.	4.2	233.	3.4	272.
175	1.8	153.	---	---	3.6	236.	4.3	240.	3.6	277.
200	3.0	106.	1.5	201.	3.5	237.	4.1	248.	3.6	286.
225	---	---	1.4	137.	3.8	247.	4.2	258.	4.0	293.
250	4.2	91.	1.5	185.	4.1	248.	4.0	267.	3.8	298.
275	4.6	146.	1.3	195.	4.0	260.	4.2	273	3.9	306.
300	---	---	---	---	3.8	253.	4.0	286.	3.8	315.
325	---	---	2.6	82.	.0	0.	4.0	293	4.0	317.
350	---	---	.8	205.	.0	0.	2.5	343.	4.6	322.
375	---	---	.0	0.	.0	0.	4.1	304.	4.1	329.
400	.0	0.	.0	0.	.0	0.	---	---	3.8	338.
425	.0	0.	.0	0.	.0	0.	.0	0.	4.2	333.
450	.0	0.	.0	0.	.0	0.	.0	0.	3.8	344.
475	.0	0.	.0	0.	.0	0.	.0	0.	5.7	346.
500	.0	0.	.0	0.	.0	0.	.0	0.	4.5	0.

TABLE 13
MAY 31, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	280	-.007	< 50	NC
0600-0700	280	-.001	< 50	NC
0700-0800	280	.014	< 50	.3
0800-0900	281	.024	100	.4
0900-1000	282	.034	150	.6
1000-1100	283	.059	360	.9
1100-1200	282	.040	150	.6
1200-1300	284	.114	450	1.3
1300-1400	284	.055	450	1.0
1400-1500	284	.037	450	.9
1500-1600	283	.034	360	.8
1600-1700	284	.068	450	1.0
1700-1800	286	.021	630	.8
1800-1900	286	.003	630	.8
1900-2000	286	.003	630	.4

3.1.6 - June 9, 1983

On June 9, 1983 five exceedances of the half-hour standard for ground level SO_2 concentration occurred. There were also four exceedances of the one-hour criterion at the same locations, approximately 3.5 to 4.5 kilometers north-west of the Plant in the vicinity of the MTC garage. Highly variable concentration readings were reported throughout this windy, monitoring day and the exceedances were reported intermittently from 930 to 1600 hours. Figure 29 shows the relative location of the Plant and the monitors reporting exceedances. Also tabulated on Figure 29 are the average SO_2 concentrations reported during the exceedance periods.

Air Quality Monitoring

Figure 30 presents the HAC recorded on June 9 at the MTC garage plotted as a function of the time the half-hour averaging period ends. MAMu#8 recorded a SO_2 MHAC of 0.256 ppm and a peak SO_2 glc of 0.537 ppm at CFB Falconbridge. MAMu#2 recorded a SO_2 MHAC of 0.009 ppm with a peak SO_2 glc of 0.05 ppm at Bailey Corners.

The maximum SO_2 vertical burden reading of the day was 750 ppm-m at Bailey Corners at 1520. A selection of these runs from Sudbury Airport to Bailey Corners is shown on Figure 32.

Figure 33 shows the half-hour average SO_2 concentrations recorded one kilometer north of Bailey Corners (UTM 5136; 51624). Between 1500 and 1554, the SO_2 glc's were in excess of 0.3 ppm, with the MHAC being 0.587 ppm and a peak glc being 2.14 ppm.

The only fixed location SO_2 monitor to report SO_2 concentrations greater than .01 ppm was Rayside, 14 kilometers north of INCO and 22 kilometers west of Falconbridge.

Emissions

Sulphur-dioxide emissions during this day ranged from a minimum of 1.8 tonnes per half-hour from 1400 to 1430 (when two roasters were operating) to a maximum of 14.5 tonnes per half-hour from 1500 to 1530 (when one roaster was operating directly to the stack plus two converters whose blowing time totalled 49 minutes). Prior to 1500, two roasters operated throughout the day. Either one or two converters operated for part of each half-hour except between 1400 and 1430. Emissions during the day were typically between 3.5 and 5.5 tonnes per half-hour except when the acid plant was by-passed between 1500 and 1600, at which time emissions rose to 14.5 and 12.5 for the two half-hour periods during this hour. No emissions data is available after 1600 hours.

Synoptic Meteorology

On June 9, a slow-moving low pressure system tracked across the upper Great Lakes. As the associated frontal wave remained to the west of the Sudbury region, the area was subjected to persistent south to south-easterly flows. Cloudy to overcast skies occurred, with rainshowers in the morning and a thundershower in the evening. Temperatures ranged from a low of 6°C in the morning to an afternoon maximum of 11°C. Surface winds in the morning and afternoon were from the south to south-east, with speeds typically between 15 and 33 km/h. Figure 34 shows the 1000 hours surface weather map for June 9.

For the period of high SO_2 readings at around noon, the prevailing local weather showed surface winds from the south to south-south-east, with speeds typically between 10 and 20 km/h. Skies were overcast and light rainshowers occurred.

Boundary Layer Development

The early morning minisonde temperature profile showed a strong ground based inversion up to 300 meters. The mixed layer height estimated from the surface temperature did not exceed 150 meters during the day due to the overcast conditions.

Through the entire day the winds were strong, with speeds in the range of 7 to $10 ms^{-1}$ (Tables 14a-14b - pages 46-47). The wind speed and direction showed strong gradients in the vertical. The wind speed increased with height and the wind direction changed by more than 20°, indicating that turbulence in the boundary layer may have been shear-dominated. This type of situation probably occurs most frequently in the winter months when boundary layer turbulence is characterized by strong wind shear in a stable stratified environment. Mixing within the boundary layer is probably caused by large eddies which form as a result of the interaction between strong winds and the uneven surface topography in the Falconbridge area.

Table 15 (page 48) summarizes the boundary layer parameters for this day. The surface heat flux remains low until 1200 hours due to the low level clouds causing overcast skies. After 1200, the cloud cover was not dense and some surface heating did occur. The mixed layer height remained low, however, and the convective velocity scale remained small throughout the day. The ratio of $V/W*$ was much greater than 6 (the upper limit for convection), indicating that this day was not convective when classified according to this ratio.

TABLE 14a

JUNE 9, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	930-1000		1000-1030		1100-1130		1130-1200	
H	U BAR	DIR	U BAR	DIR	U BAR	DIR	U BAR	DIR
(M)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)	M/SEC	(DEG)
50	6.7	158.	-	-	6.1	158.	7.0	161.
75	7.3	142.	6.8	149.	6.6	151.	7.2	152.
100	7.7	144.	7.5	145.	6.8	146.	7.8	160.
125	8.8	150.	8.3	157.	8.3	141.	8.5	165.
150	9.4	161.	9.4	159.	9.1	142.	9.3	154.
175	10.2	158.	9.9	174.	9.2	155.	9.3	159.
200	11.2	167.	10.7	161.	9.8	159.	10.4	171.
225	.0	0.	11.1	165.	8.1	169.	11.0	173.
250	.0	0.	12.4	169.	11.2	166.	10.9	168.
275	.0	0.	12.0	170.	11.5	163.	12.4	173.
300	.0	0.	.0	0.	1.7	168.	13.0	173.
325	.0	0.	.0	0.	2.3	174.	13.0	181.
350	.0	0.	.0	0.	.0	0.	13.0	181.
375	.0	0.	.0	0.	.0	0.	.0	0.
400	.0	0.	.0	0.	.0	0.	.0	0.
425	.0	0.	.0	0.	.0	0.	.0	0.
450	.0	0.	.0	0.	.0	0.	.0	0.
475	.0	0.	.0	0.	.0	0.	.0	0.
500	.0	0.	.0	0.	.0	0.	.0	0.

TABLE 14b

JUNE 9, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1200-1230		1230-1300		1500-1530		1530-1600	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	6.6	163.	3.9	147.	8.4	162.	7.8	163.
75	6.9	156.	5.0	146.	8.2	165.	8.1	187.
100	7.3	162.	5.3	155.	9.5	172.	-	-
125	8.0	156.	6.7	154.	10.1	179.	9.9	179.
150	8.4	173.	7.1	151.	-	-	9.5	161.
175	9.0	167.	8.0	152.	-	-	10.3	153.
200	9.3	170.	8.4	153.	-	-	-	-
225	9.9	165.	8.7	164.	.0	0.	-	-
250	10.6	168.	9.4	163.	.0	0.	.0	0.
275	11.4	172.	10.7	160.	.0	0.	-	-
300	11.8	173.	11.2	170.	.0	0.	.0	0.
325	12.8	169.	11.6	168.	.0	0.	.0	0.
350	-	-	12.4	167.	.0	0.	13.0	174.
375	13.2	184.	13.3	173.	.0	0.	.0	0.
400	.0	0.	14.1	177.	.0	0.	-	-
425	.0	0.	12.8	179.	.0	0.	.0	0.
450	.0	0.	11.8	168.	.0	0.	.0	0.
475	.0	0.	.0	0.	.0	0.	.0	0.
500	.0	0.	.0	0.	.0	0.	.0	0.

TABLE 15
JUNE 9, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	291	-.005	50	NC
0600-0700	291	-.001	50	NC
0700-0800	291	.001	50	.1
0800-0900	291	.007	50	.2
0900-1000	291	.009	50	.2
1000-1100	291	.004	50	.2
1100-1200	291	.009	50	.2
1200-1300	292	.040	80	.2
1300-1400	294	.062	125	.6
1400-1500	293	.034	100	.5
1500-1600	294	.055	125	.6
1600-1700	294	.037	125	.5
1700-1800	294	.027	125	.5
1800-1900	295	.022	150	.5
1900-2000	294	-	125	-

3.1.7 - June 20, 1983

The exceedance of the half-hour standard for SO_2 ground level concentration recorded this day was monitored at a site just south of the MTC garage and approximately 2.5 kilometers west of the Plant. Figure 36 shows the position of this monitor with respect to the Falconbridge stack. Also noted on Figure 36 is the concentration recorded during the exceedance. No exceedance of the one-hour criterion was detected.

Air Quality Monitoring

MAMu#7 positioned #2 at Elmsview and Dominion Roads in Val Caron at 915 and recorded an SO_2 vertical burden of 180 ppm-m. MAMu#2 recorded a MHAC of SO_2 of 0.067 ppm and a peak SO_2 glc of 0.172 ppm. MAMu#1 commenced acquiring data at 1008 at the Fisher Pit entrance and recorded an SO_2 MHAC of 0.429 ppm, with a peak SO_2 glc of 1.55 ppm. Figure 37 presents the HAC recorded by MAMu#1 at this location.

MAMu#7 traversed the Radar Road in the vicinity of MAMu#1 and #8. Figure 38 presents the Cospec traverses during this period. Marked on the profiles are the locations of MAMu#1 and 8 indicated by the numbers 1 and 8 respectively. MAMu#8 had set up on Radar Road, 1.3 kilometers north of the Falconbridge Road (UTM 5117; 51583). The maximum five-minute glc SO_2 average was 0.078 ppm.

Between 1300 and 1400 the wind shifted from south-east to south; hence, MAMu#1 moved to the Airport Pit entrance on Airport Road and commenced acquiring data at 1411, MAMu#2 also moved to the Sudbury Flying Club and MAMu#8 moved to the MTC garage.

MAMu#1 stayed at the Airport Pit until 1631 and recorded an SO_2 MHAC of 0.122 ppm, with a peak SO_2 glc of 0.347 ppm. MAMu#2 remained at the Flying Club area until 1555 and recorded a SO_2 MHAC of 0.046 ppm and a peak SO_2 glc of 0.337 ppm. MAMu#8 acquired data at the MTC garage until 1655 and recorded a SO_2 MHAC of 0.065 ppm and a five-minute peak glc of 0.129 ppm.

During the day of June 20, only the fixed monitor at Rayside reported half-hour average concentrations greater than .01 ppm.

Emissions

Preceding the period of the exceedance, emissions from 900 to 930 were calculated to be 4.8 tonnes SO_2, with two roasters operating full-time and one converter operating for 21 minutes. From 930 to 1000, emissions were calculated to be 6.2 tonnes from two roasters and one full-time converter. The roasters continued to operate through the entire day. Emissions fell to 2.3 tonnes measured from 1000 to 1030 when only seven minutes of converter time was logged. They were 4.4 tonnes measured from 1030 to 1100 for 12 minutes of converter operation.

Synoptic Meteorology

A high pressure cell, centred north of the upper Great Lakes, dominated the weather on June 20. The high pressure system moved slowly eastward through the day. The weak pressure gradient over the Sudbury area resulted in light south to south-east flows by mid-morning. Sunny conditions prevailed, with a morning minimum of 15°C and an afternoon maximum of 29°C. From mid-morning to afternoon, south to south-east surface winds with speeds of 5 to 15 km/h occurred.

The high SO_2 incident occurred on June 20 near 1000. At that time, skies in the Sudbury area were clear. The surface winds were from the east to east-south-east, with speeds in the 5 to 10 km/h range. Figure 39 presents the 1000 hours surface weather map.

Boundary Layer Development

The period of interest is between 1000 and 1100 on this day. The mixed layer heights estimated from the minisonde temperature profile at 700 (Figure 40) and surface temperatures at other hours grew from about 50 meters at 800 to 1,200 meters at 1700, after which it steadily decreased. The mixed layer height from 1000 to 1100 was 150 meters.

The mixed layer winds were light at this hour. The average mixed layer wind speed was about 2.8ms^{-1}. Wind speed shear within the mixed layer was not significant; however there was some wind direction shear. The latter may again be attributed to the light wind conditions and local topography. Table 16 (page 52) presents the winds recorded by the acoustic sounder for the half-hour periods between 1000 and 1100 hours.

W* for the day reached a peak value of 1.6ms^{-1} at 1500. During the hour of interest, W* was 0.9ms^{-1} . V/W* was about 2 to 3, suggesting that the boundary layer was convective. Table 17 (page 53) presents a summary of boundary layer parameters of this day.

TABLE 16
JUNE 20, 1983
ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1000-1030		1030-1100	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	2.1	88.	2.1	124.
75	3.4	110.	2.3	113.
100	3.6	108.	1.9	87.
125	3.6	92.	2.3	125.
150	3.8	96.	1.5	126.
175	4.2	82.	2.0	151.
200	3.0	90.	.8	81.
225	3.9	94.	2.9	145.
250	4.4	87.	-	-
275	4.5	91.	1.7	53.
300	3.2	83.	1.8	17.
325	2.9	105.	1.4	307.
350	3.7	137.	-	-
375	3.0	136.	-	-
400	.0	0.	10.3	107.
425	.0	0.	.0	0.
450	.0	0.	.0	0.
475	.0	0.	.0	0.
500	.0	0.	.0	0.

TABLE 17

JUNE 20, 1983

SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	291	-.007	< 50	NC
0600-0700	291	.007	< 50	.2
0700-0800	293	.034	< 50	.4
0800-0900	295	.071	65	.5
0900-1000	297	.110	100	.7
1000-1100	300	.141	150	.9
1100-1200	300	.170	150	1.0
1200-1300	301	.185	200	1.1
1300-1400	302	.192	200	1.1
1400-1500	302	.189	200	1.1
1500-1600	303	.169	700	1.6
1600-1700	303	.137	700	1.5
1700-1800	304	.080	1200	1.6
1800-1900	303	.040	700	1.0
1900-2000	302	.012	400	.6

3.1.8 - June 21, 1983

Four exceedances of the half-hour ground level concentration standard for SO_2 were recorded on this day in the area of Bailey Corners. Two exceedances of the one-hour ground level criterion of .25 ppm of SO_2 were also observed in the same region located approximately 4 kilometers north-north-west of the Falconbridge Plant. Figure 41 shows the relative location of the monitors detecting exceedances as well as the Falconbridge stack. Tabulated on the right-hand side of the figure is the average concentrations recorded during the exceedance periods.

Air Quality Monitoring

MAMu#8 set up at the MTC garage and found SO_2 glc's in excess of 0.3 ppm (the half-hour standard) between 1000 and 1105. For this survey period, MAMu#8 obtained a SO_2 MHAC of 0.410 ppm and a maximum five-minute average SO_2 glc of 0.486 ppm. Figure 42 presents the HAC recorded by MAMu#8 during this monitoring period. The Cospec traversed along Radar Road and found the Centre of the plume over the garage at 1020 (165 ppm-m) and at 1040 (270 ppm-m).

At 1130, the Cospec reported a maximum at the Airport Pit entrance (750 ppm-m). MAMu#1 remained at the Airport Pit. At this location MAMu#1 reported SO_2 glc in excess of the standard, with the MHAC being 0.536 ppm and a peak glc being 1.108 ppm. Figure 43 shows a plot of MAMu#1's half-hour concentration averages.

Just before 1200, the Cospec traversed past CFB Falconbridge up to Highway #69. It reported strong SO_2 signal just west of CFB Falconbridge and continued to Highway #69, with a peak SO_2 vertical burden in excess of 900 ppm-m at the trailer park on Highway #69 (UTM 5075; 51645). This was the Inco plume which was, however, clearly separated from the Falconbridge plume and not interfering at the monitoring locations. Between 1125 and 1215 MAMu#2 recorded SO_2 glc's in excess of the standard at Bailey Corners, with a MHAC of 0.346 ppm and a SO_2 peak glc of 0.853 ppm. Figure 44 presents the data from MAMu#2 for this period.

At 1200, the Cospec returned to the Airport Road and traversed from Bailey Corners to the DND compound to Boland's Bay until 1345. It found the maximums slowly shifting eastward (1200 at the airport entrance 810 ppm-m; 1230 at UTM 4180; 51643 410 ppm-m; 1330 at the Flying club 225 ppm-m; 1345 between the DND compound and gully east of the airport 375 ppm-m). Figure 45 shows two Cospec profiles taken around this time period.

The Falconbridge area fixed monitors measured .01 ppm or less as the half-hour average SO_2 concentrations prior to 1100. After 1000, SO_2 concentrations at the fixed monitors generally began to increase. Half-hour average SO_2 concentrations between approximately .05 and .20 ppm were measured at Hanmer, Skead, Callum, Rayside and at the urban Sudbury monitor at Ash Street.

Emissions

Emissions were very low prior to 1230 on this day, measured to be less than 1.3 tonnes per half-hour, with only one roaster operating.

Synoptic Meteorology

A quasi-stationary broad ridge of high pressure covered the area on June 21. Although the airflow was highly variable, the period from mid-morning to afternoon was dominated by south-south-westerly winds, with speeds in the 5 to 20 km/h range. Skies were mainly clear and temperatures ranged from a low of 18°C to an afternoon maximum of 30°C. The 1000 hours surface weather map is presented in Figure 46.

The highest SO_2 average concentration for the exceedances on June 21 occurred near 1130, at which time the winds in the Sudbury area were basically from the south at 5 to 10 km/h. Skies were sunny with about 1/10th cloud cover.

Boundary Layer Development

The period of interest on this day is between 1000 and 1230. The mixed layer heights, estimated from both minisonde profile at 700 (Figure 47) and from surface temperatures, grew from less than 50 meters at 800 to a maximum value of 1,000 meters at 1700. The mixed layer height between 1000 and 1230 varied between 135 meters and approximately 315 meters.

The winds were light, varying between 2 and 4 ms^{-1} within the mixed layer. Average mixed layer wind speed was about 2.8 ms^{-1}. The mixed layer wind speed shear was not significant. Wind direction showed marked vertical variation which may again be attributed to light wind conditions and local topography. Half-hour average winds for the period of interest are presented in Table 18 (page 57).

The convective velocity scale W* reached a peak value of 1.6 ms^{-1} at 1500. From 1000 to 1200 W* varied between 0.9 and 1.3 m^{-1}. V/W* varied between 1.5 and 3, suggesting that the boundary layer was highly convective. The boundary layer parameters for this day are summarized on Table 19 (page 58).

TABLE 18

JUNE 21, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1000-1030		1030-1100		1100-1130		1130-1200	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	2.2	163.	1.5	158.	2.0	175.	2.3	182.
75	2.0	167.	2.3	174.	3.3	152.	3.1	200.
100	2.5	175.	3.0	117.	2.6	198.	5.0	191.
125	2.6	178.	2.6	167.	2.0	196.	-	-
150	1.6	177.	2.7	156.	2.3	112.	5.2	193.
175	3.9	178.	2.3	190.	2.8	159.	-	-
200	1.8	191.	2.7	147.	6.5	137.	3.0	262.
225	.7	229.	1.9	201.	3.1	139.	2.1	251.
250	1.1	192.	1.4	237.	-	-	-	-
275	.6	269.	.7	259.	4.4	139.	-	-
300	.7	208.	1.8	76.	3.5	154.	1.3	289.
325	-	-	-	-	-	-	-	-
350	1.8	238.	1.2	261.	-	-	-	-
375	1.3	245.	.4	292.	1.5	79.	-	-
400	2.1	255.	1.7	264.	2.9	175.	-	-
425	.0	0.	1.0	245.	-	-	-	-
450	.0	0.	.0	0.	1.2	268.	-	-
475	.0	0.	.0	0.	1.0	299.	.0	0.
500	.0	0.	.0	0.	1.5	279.	.0	0.

TABLE 19
JUNE 21, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	293	-.008	< 50	NC
0600-0700	293	.003	< 50	.2
0700-0800	294	.023	< 50	.3
0800-0900	295	.072	< 50	.5
0900-1000	298	.081	75	.6
1000-1100	300	.144	135	.9
1100-1200	301	.165	165	1.0
1200-1300	302	.191	315	1.3
1300-1400	303	.201	450	1.5
1400-1500	303	.198	450	1.5
1500-1600	304	.171	600	1.6
1600-1700	304	.141	600	1.5
1700-1800	305	.101	1000	1.5
1800-1900	304	.056	600	.8
1900-2000	303	.019	450	.7

3.1.9 - June 24, 1983

One exceedance of the half-hour SO_2 standard for ground level concentrations was recorded on June 24 by a mobile monitor located on Highway #17 near Wahnapitae, approximately nine kilometers south-east of the Falconbridge Plant. Figure 48 presents the relative location of the monitor with respect to the Plant and summarizes the time and observed average concentration of the exceedance.

Air Quality Monitoring

The Cospec logged eight computer runs from 915 to 1145 along Highway #17 between the Wahnapitae River on the west and Kukagami Lake Road on the east. Figure 49 presents a selection of the Cospec traverses. A maximum SO_2 optical concentration depth of 260 ppm-m was recorded at Spencer Road at 1018.

MAMu#8 remained at the transformer site just east of Wahnapitae (UTM 5202; 51502) until 1145 and between 1020 and 1055 recorded SO_2 glc data in excess of the standard, with a MHAC of 0.320 ppm and a maximum five-minute average SO_2 glc of 0.320 ppm. Figure 50 presents MAMu#8's monitoring results. MAMu#1 remained at Norwick Drive on Highway #17 (UTM 5212; 51499) until 1148 and recorded a SO_2 MHAC of 0.196 ppm and a maximum SO_2 glc of 0.265 ppm. MAMu#2 monitored at Spencer Road on Highway #17 until 1302 and recorded a SO_2 MHAC of 0.121 ppm and a peak SO_2 glc of 0.200 ppm.

After 1148, MAMu#1 moved eastward to a private drive located one kilometer west of Kukagami Lake Road on Highway #17. It started gathering data at this site at 1206 and remained until 1251. MAMu#1, at this second site, recorded a SO_2 MHAC of 0.012 ppm, with a peak SO_2 glc of 0.049 ppm.

Early this day only traces of SO_2 were detected at all monitors in the study area. At approximately 1120, the Laurentian Hospital site located approximately four kilometers south-east of INCO recorded high SO_2

readings. Subsequently, SO_2 concentration increased at other monitors in Coniston, Burwash, Callum and Hanmer to half-hour average value of approximately .03 to .07.

Emissions

Emissions from 900 to 930 were measured to be 5.6 tonnes, with two roasters operating full-time plus one converter for 10 minutes. From 900 to 1030 two roasters plus 25 minutes of converter operation per half-hour produced 7.7 and 6.2 tonnes per half-hour for the first and second half-hour periods respectively. From 1030 to 1100, emissions were 5.1 tonnes from two roasters plus 20 minutes of converter operation.

Synoptic Meteorology

On June 24, the Sudbury area remained under the influence of a quasi-stationary high pressure system centred just south of Lake Superior. Skies were generally clear in the early morning, becoming cloudy by mid-morning and persisting for the rest of the day. Some scattered rainshowers occurred in the early evening. The airflow initially was light northerlies but became more west to north-westerlies by late morning and afternoon, with speeds in the range of 10 to 40 km/h. Temperatures ranged from a minimum of 13°C in the morning to an afternoon maximum of 26°C.

The prevailing local weather in the Sudbury area consisted of cloudy skies, with surface winds from the north-west to north-north-west at about 5 km/h. Figure 51 shows the 1000 surface weather map.

Boundary Layer Development

The period of interest on this day is between 1000 and 1100. The mixed layer height, estimated from the minisonde temperature profile shown in Figure 52 and from surface temperatures, increased from 50 meters at 700 to above 2,000 meters at 1500 and decreased thereafter. Between 1000 and 1100 the mixed layer height was 150 meters. The boundary layer was not in a steady state as the mixed layer was growing rapidly at that time.

The mixed layer winds summarized on Table 20 (page 62) were light, with an average wind of about 2 ms^{-1}. Although the vertical wind speed shear was not significant, wind direction showed marked changes in the vertical, perhaps due to the combined effects of light winds and complex topography.

The convective velocity scale reached a peak value of 2.4ms^{-1} at 1500. Between 1000 and 1100, W* was 0.7 ms^{-1}. V/W* was about 3, suggesting that the boundary layer was convective. Thus turbulence in the layer was the effect of heat convection, with perhaps some influence from wind shear. Table 21 (page 63) summarizes W* and other boundary layer variables for this day.

TABLE 20

JUNE 24, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1000-1030		1030-1100	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	1.9	357.	.9	347.
75	2.4	360.	2.0	147.
100	2.3	313.	1.3	86.
125	1.9	299.	2.4	111.
150	2.8	312.	2.9	116.
175	3.2	310.	2.2	130.
200	2.7	299.	1.6	192.
225	2.0	321.	.8	184.
250	2.3	300.	3.3	147.
275	1.8	311.	-	-
300	2.4	311.	4.7	59.
325	2.8	297.	4.8	54.
350	3.3	303.	-	-
375	3.1	301.	4.1	46.
400	2.5	283.	-	-
425	2.9	283.	2.0	303.
450	3.4	294.	-	-
475	-	-	2.7	294.
500	3.5	296.	2.5	303.

TABLE 21
JUNE 24, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	287	-.009	< 50	NC
0600-0700	287	.002	< 50	.2
0700-0800	288	.023	50	.3
0800-0900	289	.038	65	.4
0900-1000	292	.060	100	.6
1000-1100	293	.058	150	.7
1100-1200	294	.079	350	1.0
1200-1300	295	.091	1000	1.6
1300-1400	296	.104	1600	2.0
1400-1500	297	.109	2000	2.2
1500-1600	298	.134	> 2000	2.4
1600-1700	297	.088	1500	1.9
1700-1800	297	.060	1500	1.6
1800-1900	295	.040	1000	1.2
1900-2000	295	.018	1000	.9

3.1.10 - June 25, 1983

Early in the morning of this day, exceedance of both the half-hour ground level standard and of the one-hour criterion occurred at the Coniston fixed monitor approximately 10 kilometers south-south-west of the Falconbridge Plant. Figure 53 shows the location of the Coniston monitor with respect to the Falconbridge stack and tabulates the observed average concentrations during the exceedances.

Air Quality Monitoring

The fixed monitor located at Coniston reported that, beginning at 810, the half-hour SO_2 concentration standard of .3 ppm was exceeded at this site. The exceedance continued for the periods from 810 to 840 through 830 to 900. The one-hour standard was also briefly exceeded at this location. After 900, no SO_2 was detected at Coniston or other fixed monitors in the area.

MAMu#8 set up west of the Wahnipitae River (UTM 5159; 51479) and commenced monitoring at 915. MAMu#2 set up east of the Wahnipitae River (UTM 5167; 51480) and commenced monitoring at 937. MAMu#1 set up one kilometer east of Wahnipitae (UTM 5178; 51482) and started monitoring at 943.

A selection of Cospec runs is shown in Figure 54. One notices the gradual shifting of the plume direction. At 845, the centre of the Falconbridge plume was located over the Filtration plant (UTM 5138; 51481) two kilometers west of Wahnipitae; at 1000 it was centred over the Wahnipitae River; at 1230 it was over Norwick Drive and at 1430 it was centred over Sunset Road. The maximum SO_2 vertical burden recorded by the Cospec for this day was 358 ppm-m, recorded at the Wahnipitae River at 940.

MAMu#8 remained at the Wahnipitae River site until 1045 and for this period recorded a SO_2 MHAC of 0.104 ppm and a maximum five-minute average SO_2 glc of 0.340 ppm. MAMu#2 also remained at its site until

1057 and recorded a SO_2 MHAC of 0.162 ppm and a peak SO_2 glc of 0.213 ppm. MAMu#1 remained at its site, one kilometer east of Wahnipitae, until 1103 and recorded a SO_2 MHAC of 0.142 ppm and a peak SO_2 glc of 0.223 ppm.

MAMu#8 remained at site UTM 5202; 51502 until 1450 during which time it recorded a SO_2 MHAC of 0.066 ppm and a maximum five-minute SO_2 average glc of 0.105 ppm. MAMu#2 remained at Spencer Road until 1437 and recorded a SO_2 MHAC of 0.069 ppm and a peak SO_2 glc of 0.120 ppm. MAMu#1 remained at Sunset Road until 1446 and recorded a SO_2 of 0.080 ppm and a maximum peak SO_2 glc of 0.134 ppm.

Emissions

Emissions were not recorded before 900. From 900 to 930 they were calculated to be 5.7 tonnes, with both roasters operating plus 25 minutes of converter operation time divided between two converters.

Synoptic Meteorology

A broad region of high pressure persisted over the Great Lakes during June 25. North to north-west flows prevailed over the Sudbury region until early afternoon in advance of the ridge line, after which south to south-west flows developed. Skies were clear and temperatures rose from a morning minimum of 8°C to an afternoon maximum of 24°C. Surface wind speeds were in the range of 5 to 20 km/h. Figure 55 presents the 1000 surface weather map.

On June 25, the highest SO_2 readings were observed around 800. At this time, the Sudbury area experienced sunny skies (1/10th cloud cover) and north to north-west surface winds at speeds of 5 to 10 km/h.

Boundary Layer Development

The exceedances on this day occurred during the period from 800 to 900. The mixed layer heights derived from the minisonde temperature profile of 710 (Figure 56) and the surface temperatures at other hours increased from about 50 meters at 700 to about 1,650 meters at 1500. They remained fairly steady up to 1800 and decreased thereafter. The mixed layer height from 800 to 900 was approximately 150 meters.

The mixed layer wind speeds from 800 to 900 were light, varying between 2 and 3 ms^{-1}. The wind direction showed substantial variation, with height, perhaps, as a consequence of low wind speed and topography. Average mixed layer wind speed during the one-hour period from 800 to 900 was about 2.5 ms^{-1}. Table 22 (page 67) summarizes the half-hour average winds measured by acoustic sounder for this period.

The convective velocity scale, W^*, reached a peak value of 2.2 ms^{-1} at 1400. During the period from 800 to 900 it was about 0.7 ms^{-1}. Thus, V/W^* was about 3.5 which implies that the boundary layer was convective. Table 23 (page 68) presents a summary of boundary layer parameters for this day.

TABLE 22

JUNE 25, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	800-830		830-900	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	2.3	9.	1.6	29.
75	2.9	20.	1.6	68.
100	3.1	11.	1.9	30.
125	2.9	3.	1.7	19.
150	2.9	5.	2.3	4.
175	3.2	12.	1.3	77.
200	3.1	9.	1.6	53.
225	3.5	13.	2.0	41.
250	3.7	8.	2.0	16.
275	3.8	5.	1.1	1.
300	4.0	353.	1.7	347.
325	3.2	353.	1.5	342.
350	3.3	346.	2.8	349.
375	3.4	338.	2.8	355.
400	3.1	336.	3.1	345.
425	-	-	3.1	1.
450	-	-	1.4	17.
475	.0	0.	3.3	358.
500	.0	0.	-	-

TABLE 23
JUNE 25, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	282	-.010	< 50	NC
0600-0700	282	.012	< 50	.3
0700-0800	284	.022	65	.4
0800-0900	286	.053	150	.7
0900-1000	287	.094	750	1.4
1000-1100	289	.130	1100	1.8
1100-1200	291	.160	1200	2.0
1200-1300	292	.170	1300	2.1
1300-1400	293	.175	1350	2.2
1400-1500	294	.168	1400	2.2
1500-1600	296	.132	1650	2.0
1600-1700	296	.076	1650	1.8
1700-1800	296	.066	1650	1.7
1800-1900	295	.027	1500	1.2
1900-2000	294	.012	1400	.9

3.1.11 - June 27, 1983

Two exceedances of the half-hour SO_2 standard were recorded this day in the Happy Valley area south of the Falconbridge Plant. Figure 57 shows the relative location of the monitor recording the exceedances with respect to the Plants. Also tabulated on this figure are average concentrations recorded during the exceedances.

Air Quality Monitoring

As the flow was north-easterly and was forecast to be persistent for the day, MAMu#1 set up at Norway Lake in Happy Valley, MAMu#2 set up along the Garson - Coniston Highway and MAMu#8 set up approximately four kilometers west of Coniston on Highway #17.

Cospec's maximum reading was recorded on the Garson - Coniston Line Road at 1007, with a reading of 660 ppm-m (UTM 5117; 51532). At 1343, it recorded a maximum of 160 ppm-m on Highway #17 near MAMu#8's location. Figure 58 displays a series of Cospec traverses. Note that MAMu#2 and MAMu#8 were directly under the Falconbridge plume at varying distances down-wind.

MAMu#8 remained at site UTM 5099; 51488 until 1355 and recorded a SO_2 MHAC of 0.202 ppm and a peak five-minute average SO_2 glc of 0.237 ppm. MAMu#2 stayed at the Garson - Coniston Line Road until 1531 and it recorded a SO_2 MHAC of 0.113 ppm and a peak SO_2 glc of 0.532 ppm. Meanwhile, up to 1522, MAMu#1 had recorded a SO_2 MHAC of 0.307 ppm and a peak SO_2 glc of 1.147 ppm in Happy Valley. Figure 59 presents the HAC record for MAMu#1.

MAMu#8 re-located in Happy Valley at the foot of the escarpment (UTM 5515; 51575) and started to gather data at 1420. MAMu#2 moved over to the Falconbridge area and set up on top of the hill at the west end of the Lakeshore Road (UTM 5145; 51577) and began acquiring data at 1602. MAMu#1 remained at the Norway Lake site in Happy Valley.

Figures 60 and 61 show the half-hour average concentrations measured by MAMu#1 and MAMu#8 respectively, plotted as functions of the time ending the averaging periods.

On essentially all traverses between 1500 and 1915, the Cospec obtained very high SO_2 readings (in excess of 1000 ppm-m) and a very narrow plume width as typified by the 1717 profile shown on Figure 58.

Between 1528 and 1908 MAMU#1 recorded a SO_2 MHAC of 0.355 ppm and a peak SO_2 of 1.263 ppm, with excursions above the 0.3 ppm standard between 1558 and 1648. Between 1602 and 1907 MAMu#2 recorded a SO_2 MHAC of 0.398 ppm and a peak SO_2 glc of 3.295 ppm, with excursions above the 0.3 ppm standard between 1602 and 1637. Between 1420 and 1910, MAMu#2 recorded a SO_2 MHAC of 0.048 ppm and a maximum five-minute SO_2 average glc of 0.117 ppm.

No significant (~ .01 ppm) average concentrations of SO_2 were reported at the fixed monitors, with the exception of Mikoka and Long Lake which are located south-east and south respective of INCO stacks.

Emissions

Looking at the hour preceding this fumigation period, emissions from 1000 to 1030 were calculated to be 5.6 tonnes, for one roaster and one converter operating for the full half-hour. From 1030 to 1100 emissions dropped to less than 1.0 tonne, with only one roaster operating. During the hour of interest from 1100 to 1130, 7.1 tonnes were measured to be emitted from two roasters, one of which was vented directly to the stack. From 1130 to 1200, 7.6 tonnes resulted from the operation of two roasters plus 20 minutes of converter operation and venting one roaster directly to the stack for 15 minutes.

Preceding the second period of interest (from 1500 to 1530), the two converters operated for 30 minutes each but no roasters were being used; emissions were measured to be 8.2 tonnes. Only one converter operated from 1530 to 1600, producing 6.3 tonnes SO_2. Emissions were not recorded after 1600.

Synoptic Meteorology

On June 27, the Sudbury area was under the influence of three frontal systems which pushed slowly southward through the day. As a result, the region experienced persistent north to north-easterly flows, with speeds typically between 15 and 35 km/h until early evening. Overcast skies with drizzle in the early morning gave way to mainly sunny skies by 600. Temperatures ranged from a minimum of 7°C to an afternoon maximum of 18°C. Figure 62 presents the 1000 hours surface weather map for this day.

On this day, two separate high SO_2 incidents were noted, one in the morning around 1100 and the other at around 1600. For the morning situation, the weather in the Sudbury area was mainly sunny (1/10th sky cover), with surface winds from the north-north-east to north-east at 20 to 30 km/h. Skies remained sunny in the afternoon and at 1600, the surface winds were still from the north-north-east to north-east, with speeds 10 to 20 km/h.

Boundary Layer Development

There were two periods when exceedances occurred on this day. The first was between 1100 and 1200 and the second between 1600 and 1700. The mixed layer heights estimated as before increased from about 350 meters at 700 to a peak value of 850 meters at 1700. The finite mixed layer height during the early morning hours may be a cause of the cold front which passed over the area. The initial mixed layer was capped by a strong stable layer (Figure 63). This, together with overcast conditions, did not allow the mixed layer to show substantial growth later in the day. The mixed layer heights during the period from 1100 to 1200 were 650 meters and from 1600 to 1700 about 800 meters.

The mixed layer winds from 1100 to 1200 and from 1600 to 1700 were brisk during these periods. The wind speeds were slightly lower during the afternoon periods. The average mixed layer winds were about 8 ms^{-1} in the morning episode and about 6 to 7 ms^{-1} in the afternoon episode.

Wind speed shear was not significant, although wind direction fluctuated markedly with height. This may be attributed to the topographical influences. Table 24 (page 73) summarizes the half-hour average winds measured by the acoustic sounder during the exceedances.

W* reached a peak value of 1.7 ms-1 at 1300. V/W* was 5 during the morning episode and 4 during the afternoon episode. This suggests that the conditions were convection during both exceedances; however, shear production of turbulent energy may have been significant which once again may be attributed to the locally complex topography.

Table 25 (page 74) summarizes the boundary layer variables on this day.

TABLE 24

JUNE 27, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1100-1130		1130-1200		1600-1630		1630-1700	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	10.0	19.	8.2	53.	7.4	354.	5.4	45.
75	9.6	22.	7.3	46.	7.1	353.	6.0	41.
100	8.6	36.	-	-	10.3	356.	5.3	40.
125	7.7	20.	7.5	43.	9.5	359.	5.3	55.
150	7.5	30.	-	-	-	-	7.2	58.
175	5.4	33.	-	-	-	-	8.6	52.
200	9.2	33.	6.5	76.	9.0	0.	6.5	60.
225	9.8	27.	-	-	-	-	6.5	61.
250	9.1	43.	7.7	71.	4.1	19.	8.6	62.
275	-	-	7.6	56.	-	-	7.2	58
300	-	-	8.8	61.	4.8	49.	-	-
325	9.0	51.	6.5	47.	-	-	-	-
350	-	-	-	-	2.0	16.	7.4	61.
375	3.4	22.	-	-	2.9	33.	-	-
400	-	-	.0	0.	5.6	49.	-	-
425	8.0	59.	.0	0.	-	-	.0	0.
450	.0	0.	.0	0.	-	-	.0	0.
475	.0	0.	.0	0.	.0	0.	.0	0.
500	.0	0.	.0	0.	-	-	.0	0.

TABLE 25
JUNE 27, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	282	-.003	450	NC
0600-0700	280	.003	350	.3
0700-0800	280	.029	350	.7
0800-0900	280	.057	350	.9
0900-1000	282	.094	500	1.2
1000-1100	283	.134	600	1.5
1100-1200	284	.161	650	1.6
1200-1300	286	.177	700	1.7
1300-1400	287	.186	700	1.7
1400-1500	288	.179	700	1.7
1500-1600	289	.159	750	1.7
1600-1700	290	.131	800	1.6
1700-1800	291	.087	850	1.4
1800-1900	291	.039	850	1.1
1900-2000	290	.017	800	.8

3.1.12 - June 28, 1983

On this final day of the field survey six separate exceedances of the half-hour standard for SO_2 ground level concentrations were measured in the town of Falconbridge. Four exceedances of the one-hour SO_2 criterion also occurred during this period. Figure 64 shows the relative position of the monitor with respect to the Falconbridge plant. Also tabulated on this figure is a summary of the average measured concentrations monitored during the exceedance periods.

Air Quality Monitoring

The minisonde ascent analyses at 528 showed a strong, low level nocturnal inversion (4°C/200m) up to 200 meters. The Falconbridge plume was above this inversion. Aloft, the winds were due east and brisk (25 to 35 km/h).

MAMu#8 set up by the railway tracks (UTM 5138; 51574) on the Falconbridge Road and commenced gathering data at 640. MAMu#2 set up at Hodge and Bennett Streets in Falconbridge (UTM 5143; 51576) and started gathering data at 603. MAMu#1 set up near the Petro-Canada garage along the Falconbridge Road in Falconbridge (UTM 5142; 51577) and commenced monitoring at 618.

Between 908 and 1158, MAMu#1 recorded excursions above the 0.3 ppm standard, with the SO_2 MHAC of 0.600 ppm and a peak SO_2 glc of 1.276 ppm. With the persistent easterly winds, MAMu#1 moved over to Garson at 1200 and positioned itself under the plume at the corner of O'Neil and Catherine Streets (UTM 5106; 51550).

MAMu#2 remained at its downtown Falconbridge site for the day (from 603 to 1335) and recorded excursions above the 0.3 ppm standard between 928 and 1158 and again between 1248 and 1333. It recorded a SO_2 MHAC of 0.888 ppm and a peak SO_2 glc of 3.733 ppm for this survey period. Figure 65 presents the HAC recorded by MAMu#2 at this site.

MAMu#8 also remained at its site until 1325 where it monitored SO_2 MHAC of only 0.044 ppm and its maximum five-minute SO_2 average was 0.074 ppm.

Figure 66 presents a selection of Cospec traverses.

Prior to 800, no SO_2 was detected at fixed monitoring network in the Falconbridge region. After 800, significant hourly average SO_2 concentrations were measured at the Garson and New Sudbury monitors 4.6 kilometers west-south-west and 12.2 kilometers south-west of the Falconbridge Plant respectively. The average concentration at Garson between 800 and 900 was .11 ppm, between 900 and 1000 it was .08 ppm, between 1000 and 1100 it was .17 ppm and between 1100 and 1200 it was .14 ppm. After 1200, the hourly average concentration was .03 ppm or less for the remainder of the afternoon. At New Sudbury for the hours 900 through 1200 the average concentration was .04, .01, .02 and .07 ppm respectively. After 1200, the average concentration was typically .04 ppm or less.

During the period of interest, the concentration of SO_2 remained below the detectable limit at all other fixed monitors except Mikkola location south-west of the Inco stacks and Ash Street in downtown Sudbury (but still to the south-west of the Falconbridge stack).

Emissions

Prior to 900, the emissions were not recorded. In the morning, emissions ranged from a minimum of 4.1 tonnes from 900 to 930 (when two roasters plus 15 minutes of converter time were recorded) to a maximum of 11.8 tonnes from 1030 to 1100 (for two roasters and 55 minutes converter operation). For most half-hour intervals, emissions were 5.0 to 7.0 tonnes. Both roasters operated during the full period and both converters were also operating for much of the period. Later in the day, the converter activity reduced to less than 10 minutes per half-hour and emissions reduced to less than 3.0 tonnes per half-hour.

Synoptic Meteorology

A quasi-stationary frontal system, oriented east to west, was located south of Lake Huron on June 28. North of Lake Superior, a quasi-stationary broad ridge of high pressure prevailed, resulting in north to north-east flows and sunny skies. Temperatures ranged from a morning minimum of 9°C to an afternoon maximum of 22°C, while surface winds persisted from the north-north-east at 5 to 15 km/h.

In the local Sudbury area, skies at that time were mainly clear (1/10th cloud cover) and the airflow was from the east to north-east at speeds of 5 to 15 km/h. Figure 67 displays the 1000 hours surface weather map for a region centred on the Falconbridge area.

Boundary Layer Development

The period of interest on this day is between 900 and 1300. The mixed layer height, estimated as before using the early morning (528 hours) minisonde profile shown in Figure 68, varied from 50 meters at 800 to a peak value of 1,500 meters at 1600, after which time it remained fairly steady. The mixed layer height rose from 150 meters between 900 and 1000 to 350 meters between 1200 and 1300. Subsequently, between 1300 and 1400 the mixed layer was 900 meters high.

Between 900 and 1000 the mixed layer winds were light. Average mixed layer wind speed for the hour was 3.5 ms^{-1}. There was no significant wind speed shear. Wind direction fluctuated markedly in the vertical, perhaps due to light wind speed and local topography. In the following hours the average mixed layer wind speed increased to 4.4 ms^{-1} between 1000 and 1100, to 8.2 ms^{-1} between 1100 and 1200 and to 8.5 ms^{-1} between 1300 and 1330. Tables 26a through 26b (pages 79-80) summarize the half-hour average winds measured by the acoustic sounder during this period.

W* for the day reached a peak value of 2.1 ms^{-1} at 1500. It was 0.8 ms^{-1} from 900 to 1000. V/W* was 4, suggesting that thermal convection played a major role in the generation of boundary layer turbulence.

Between 1000 and 1100, W* was 1.0 ms^{-1} and V/W* was 4.4. During the hour from 1100 to 1200, W* was 1.1 and V/W* was 7.5. Finally during the period from 1300 to 1400, W* was 1.5 and V/W* was 5.7. This suggests that as the day progressed shear-generated turbulence became important and that the boundary layer mixing was not solely due to convective eddies. Table 27 (page 81) summarizes the boundary layer variables for this day.

TABLE 26a

JUNE 28, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	900-930		930-1000		1000-1030		1030-1100	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)
50	2.0	15.	1.6	10.	1.7	50.	.0	25.
75	4.0	35.	4.5	35.	5.9	45.	.0	28.
100	3.6	43.	3.6	28.	5.9	44.	.0	31.
125	3.9	46.	4.1	35.	4.9	36.	4.9	31.
150	3.9	53.	4.1	38.	5.2	53.	4.7	19.
175	4.6	62.	5.0	47.	4.4	48.	4.5	1.
200	5.0	61.	5.5	52.	4.7	52.	2.4	15.
225	4.9	63.	4.7	52.	5.7	60.	-	-
250	5.9	65.	5.4	55.	5.3	58.	-	-
275	6.0	66.	3.8	52.	5.7	58.	7.3	61.
300	6.7	66.	4.1	50.	6.5	59.	-	-
325	7.3	66.	6.1	62.	5.1	53.	-	-
350	6.8	59.	7.1	66.	7.3	61.	8.8	72.
375	7.7	65.	-	-	8.1	64.	9.7	61.
400	.0	0.	-	-	-	-	-	-
425	.0	0.	-	-	5.2	59.	8.2	68.
450	.0	0.	-	-	-	-	10.7	64.
475	.0	0.	-	-	9.2	65.	.0	0.
500	.0	0.	.0	0.	.0	0.	.0	0.

TABLE 26b

JUNE 28, 1983

ACOUSTIC SOUNDER HALF-HOUR AVERAGE WINDS DURING PERIODS WHEN EXCEEDANCES WERE MEASURED

	1100-1130		1130-1200		1230-1300		1300-1330	
H (M)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG)	U BAR M/SEC	DIR (DEG
50	10.0	19.	8.2	53.	4.7	38.	5.6	15.
75	9.6	22.	7.3	46.	6.8	37.	7.0	31.
100	8.6	36.	-	-	7.9	36.	6.3	31.
125	7.7	20.	7.5	43.	-	-	7.0	39.
150	7.5	30.	-	-	11.3	8.	7.6	44.
175	5.4	33.	-	-	-	-	9.5	45.
200	9.2	33.	6.5	76.	-	-	8.5	59.
225	9.8	27.	-	-	7.3	49.	8.1	74.
250	9.1	43.	7.7	71.	7.8	54.	8.9	73.
275	-	-	7.6	56.	7.2	54.	9.2	64.
300	-	-	8.8	61.	8.1	64.	9.0	65.
325	9.0	51.	6.5	47.	-	-	10.0	60.
350	-	-	-	-	11.5	63.	9.1	61.
375	3.4	22.	-	-	.0	0.	9.3	66.
400	-	-	.0	0.	.0	0.	9.0	67.
425	8.0	59.	.0	0.	.0	0.	8.6	60.
450	.0	0.	.0	0.	-	-	10.9	65.
475	.0	0.	.0	0.	.0	0.	.0	0.
500	.0	0.	.0	0.	.0	0.	9.5	62.

TABLE 27
JUNE 28, 1983
SUMMARY OF BOUNDARY LAYER PARAMETERS

Time (EDT)	Average Surface Temperature (°K)	Average Surface Heat Flux (m°K/s)	Estimated Mixed Layer Height (m)	Convective Vertical Velocity (m/s)
0500-0600	283	-.005	< 50	NC
0600-0700	283	.008	< 50	.2
0700-0800	284	.026	< 50	.4
0800-0900	287	.056	65	.5
0900-1000	289	.093	150	.8
1000-1100	290	.126	200	1.0
1100-1200	291	.161	250	1.1
1200-1300	292	.176	350	1.3
1300-1400	293	.183	900	1.5
1400-1500	293	.179	900	1.9
1500-1600	294	.161	1300	2.1
1600-1700	295	.133	1500	2.0
1700-1800	295	.101	1500	1.9
1800-1900	295	.054	1500	1.5
1900-2000	295	.013	1500	1.0

3.2 SUMMARY OF THE OBSERVED EXCEEDANCES DURING THIS FIELD STUDY

During the months of May and June 1983, 12 monitoring days of the Falconbridge field study had SO_2 excursions above the air quality standard which were attributable to emissions from the Falconbridge smelter. On eight of these days, the synoptic conditions over the Sudbury area were dominated by slow-moving or quasi-stationary ridges of high pressure, weak pressure gradients, surface winds typically below 20 km/h and diurnal temperature ranges of 10 to 17°C. Five of these eight days were characterized by southerly flows while the other three days had northerly flows. The remaining four days of excursions were associated with frontal systems in the area. On two of these four days, quasi-stationary low pressure systems persisted along with cloudy skies, showers, southerly flows and diurnal temperature ranges of about 5°C. The other two events were associated with frontal movements southward across the area and the development of brisk northerly flows in their wakes.

The exceedances both of the half-hour standard for ground level concentrations of SO_2 and the one-hour criterion for SO_2 are summarized in Tables 28a through 28c (pages 84-86). Also exhibited are the emission rates as well as meteorological and boundary layer parameters describing the weather conditions associated with these exceedances.

Two notable points are the mean wind speeds associated with the exceedances and the average mixed layer heights calculated for the periods of the exceedances. Except on June 9 and June 28, the mixed layer average wind speeds could be classified as light to moderate. In all cases, the mixed layer height was not calculated to be greater than 1,000 meters for the exceedance periods, although at other times during the day of the field study the mixed layer was estimated to extend to heights greater than 2,000 meters. Also, for many of the exceedances, the mixed layer height was 500 meters or less.

On several occasions under light wind conditions the acoustic sounder has reported highly variable wind directions. For comparison purposes, the wind directions recorded at the upper level on the Ministry of the Environment Meteorological tower in Sudbury have been included in column 8 on Table 28. In cases when acoustic sounder wind direction is inconsistent with the orientation of the monitor with respect to the source (Falconbridge), confidence was placed in the tower winds. Tower winds were also used to fill in gaps in the acoustic sounder's record of horizontal winds.

The final column in Table 28 presents the ratio of the mean horizontal wind speed to the convective vertical velocity scale W*. This ratio has been used as a guideline for determining if the turbulence (mixing) in the mixed layer is significantly affected by shear stress. (G.E. Willis and J.W. Deardorff, Atmos. Envir. 12, pp. 1305-1311, 1978). For situations with a flat underlying surface, the limit V/W* less than or equal to 6 has been set to define boundary layers in which convection dominates the product of turbulence.

Although the complex terrain in the Falconbridge region may somewhat modify this limit, in the absence of data for rough topography, the guideline of 6 will continue to be used to determine which cases may be considered convective in the analysis of this field study data in the following sections.

TABLE 28a

SUMMARY OF EMISSIONS, BOUNDARY LAYER AND METEOROLOGICAL PARAMETERS ASSOCIATED WITH THE RECORD EXCEEDANCES DURING THE FALCONBRIDGE FIELD STUDY (MAY 5, 1983-JUNE 28, 1983)

Exceedance of Half-Hour Standard

Exceedance		Observed Average SO_2 Concentration (ppm)	[1] Location (UTM)	[2] Emission Rate SO_2 Q (tonnes/ half-hour)	[3] Surface Temperature °C	[4] V - Mean Wind Speed (ms^{-1})	Wind Direction (degrees) (Sounder/ Tower)	[5] Mixed Layer Height (meters)	[6] W* (ms^{-1})	V/W*
Date	Time									
May 5	1000-1030	.30	5148; 51565	(6.48)	1.0	5.4	40/10	500	not available	
May 11	955-1025	.67	5120; 51596	(5.50)	12.8	2.4	170/123	500	1.3	1.9
	1025-1055	.61	5120; 51596	2.40	12.8	5.5	170/123	500	1.3	4.2
	1055-1125	.35	5120; 51596	1.55	13.8	2.4	265/127	800	1.6	1.5
May 13	900- 930	.34	5186; 51678	7.84	13.8	2.4	183/208	75	0.6	4.0
	930-1000	1.10	5186; 51678	11.76	13.8	2.7	179/208	75	0.6	4.5
	1000-1030	.72	5186; 51678	10.38	16.8	3.7	193/214	100	0.7	5.3
	1030-1100	.44	5186; 51678	(4.79)	16.8	4.8	195/214	100	0.7	6.9
	1000-1030	.58	5182; 51662	10.38	16.8	3.7	193/214	100	0.7	5.3
	1120-1150	.48	5157; 51627	3.27	18.8	3.2	200/218	170	1.0	3.2
May 17	835- 905	.97	5136; 51612	(10.94)	3.8	4.0	138/133	300	0.8	5.0
	905- 935	.35	5136; 51612	10.94	5.8	3.0	165/125	800	1.4	2.1
	305- 835	.66	5136; 51612	(10.94)	3.8	4.0	138/133	300	0.8	5.0
May 31	1030-1100	.37	5142; 51619	6.24	9.8	2.8	150/161	360	0.9	3.1
	1300-1330	.58	5157; 51627	4.81	10.8	3.7	258/187	450	1.0	3.7
	1315-1345	.48	5167; 51618	4.33	10.8	3.6	279/187	450	1.0	3.6

TABLE 28b

Exceedance		Observed Average SO_2 Concentration (ppm)	[1] Location (UTM)	[2] Emission Rate SO_2 Q (tonnes/ half-hour)	[3] Surface Temperature °C	[4] V - Mean Wind Speed (ms^{-1})	Wind Direction (degrees) (Sounder/ Tower)	[5] Mixed Layer Height (meters)	[6] W* (ms^{-1})	V/W*
Date	Time									
June 9	1000-1030	.36	5136; 51612	3.89	17.8	6.0	157/193	50	0.2	30.0
	1100-1130	.32	5136; 51612	4.95	17.8	6.1	158/190	50	0.2	30.5
	1130-1200	.41	5136; 51612	4.26	17.8	7.0	161/190	50	0.2	35.0
	1230-1300	.49	5136; 51612	2.92	18.8	4.5	147/191	80	0.2	22.5
	1500-1530	.43	51624;51624	14.46	20.0	9.1	170/199	125	0.6	15.2
June 20	1009-1039	.32	5117; 51592	2.32	26.8	2.7	107/104	150	0.9	3.0
June 21	1000-1030	.31	5135; 51613	1.27	26.8	2.3	171/163	135	0.9	2.6
	1030-1100	.38	5135; 51613	1.19	26.8	2.4	154/163	135	0.9	2.7
	1130-1200	.43	5149; 51619	1.26	27.8	3.9	192/163	165	1.0	3.9
	1130-1200	.34	5138; 51618	1.26	27.8	3.9	192/163	165	1.0	3.9
June 24	1025-1055	.31	5202; 51502	5.07	19.8	1.9	161/295	150	0.6	3.2
June 25	805- 835	.37	5118; 51480	[5.71]	12.8	2.8	10/356	150	0.7	4.0
June 27	1110-1140	.31	5146; 51567	(7.12)	10.8	7.8	44/36	650	1.6	4.9
	1605-1635	.33	5146; 51567	[6.31]	16.8	6.3	176/43	800	1.6	3.9
June 28	910- 940	.41	5142; 51577	(4.11)	15.0	3.5	34/84	150	0.8	4.4
	940-1010	.34	5142; 51577	(6.51)	15.8	4.2	37/82	150	0.8	5.3
	1010-1040	.47	5142; 51577	8.45	16.8	4.1	21/79	200	1.0	4.1
	1040-1110	.40	5142; 51577	11.75	16.8	6.8	25/74	200	1.0	6.8
	1110-1140	.39	5142; 51577	9.74	17.8	8.2	39/69	250	1.1	7.5
	1300-1330	.87	5143; 51576	5.48	19.8	8.5	55/54	900	1.5	5.7

TABLE 28c

Exceedance of One-Hour Criterion

Exceedance		Observed Average SO_2 Concentration (ppm)	Location (UTM) [1]	Emission Rate SO_2 Q (tonnes/hour) [2]	Surface Temperature °C [3]	V - Mean Wind Speed (ms^{-1}) [4]	Wind Direction (degrees) (Sounder/ Tower)	Mixed Layer Height (meters) [5]	W* (ms^{-1}) [6]	V/W*
Date	Time									
May 11	1000-1100	.66	5120; 51596	(9.56)	13.0	2.4	170/123	500	1.3	1.9
May 13	900-1000	.72	5186; 51678	19.60	13.8	2.6	181/208	75	0.6	4.3
	1000-1100	.58	5186; 51678	(15.17)	16.8	4.3	194/214	100	0.7	6.1
	1000-1100	.32	5182; 51662	(15.17)	16.8	4.3	194/214	100	0.7	6.1
May 17	750- 850	.58	5135; 51612	[21.88]	4.0	4.0	138/133	300	0.8	5.0
May 31	1025-1125	.27	5142; 51619	8.93	9.3	2.3	170/168	255	0.8	2.9
	1230-1330	.32	5157; 51627	10.81	10.8	3.6	249/189	450	1.2	3.0
June 9	930-1030	.25	5136; 51612	9.71	18.0	6.7	158/191	50	0.2	33.5
	1100-1200	.36	5136; 51612	9.21	17.8	6.6	160/190	50	0.2	33.0
	1200-1300	.33	5136; 51612	8.47	18.8	5.6	153/191	80	0.2	28.0
	1500-1600	.30	5136; 51624	26.96	20.8	8.9	169/199	125	0.6	14.8
June 21	1130-1230	.32	5149; 51619	2.52	28.3	3.9	192/179	240	1.2	3.3
	1000-1100	.35	5135; 51613	2.46	26.8	2.4	162/163	135	0.9	2.7
June 25	800- 900	.29	5118; 51480	[12.22]	12.8	2.3	20/356	150	0.7	3.3
June 28	955- 955	.30	5142; 51577	(10.62)	15.8	3.5	34/84	150	0.8	4.4
	955-1055	.45	5142; 51577	20.20	15.8	4.4	34/79	200	1.0	4.4
	1055-1155	.37	5142; 51577	16.41	17.8	8.2	39/79	250	1.1	7.5
	1230-1330	.55	5143; 51576	10.89	19.8	8.4	51/63	625	1.5	5.6

[1] UTM coordinates; eastern and northern respectively in tenths of kilometers.

[2] Emissions enclosed in standard brackets ( ) indicate calculated rather than measured emissions and emissions enclosed in square brackets [ ] indicate extrapolated emissions from the following time period.

[3] Mean surface temperature calculated by averaging fixed station measurements in the Falconbridge area.

[4] Averaged through the mixed layer for the period of the exceedance.

[5] Estimated from the minisonde temperature profile and the surface temperature.

[6] Calculated according to Equation (4.1).

4.0 PATTERN FOR HIGH GROUND LEVEL CONCENTRATIONS

4.1 INTRODUCTION

The topography at Falconbridge is fairly complex. The smelter is located on a ridge rising approximately 100 meters above the valley (Happy Valley) floor. The stack is located on the rise, with approximately one-quarter of its 92-meter height below the escarpment. The valley is in the south-east quadrant with respect to the stack. Thus, for winds with a component from the south-east quadrant, the apparent stack top height is approximately 75 meters.

For flows from the south-east quadrant, the ridge will be seen as a bluff body. Wind tunnel experiments have shown that for such flows a re-circulation zone is created at the base of the escarpment. The size of the re-circulating zone will depend on the angle which the face of the escarpment subtends with the valley floor. The flow will be retarded as the escarpment is approached. As the flow goes over the escarpment, it accelerates locally. The magnitude of the acceleration depends on the steepness of the escarpment.

When the flow is from the north-west quadrant, the streamlines descend as the flow goes over the valley. Depending on the steepness of the valley walls and the wind speed, a re-circulation zone of varying intensity may form at the base of the escarpment for these flows.

For flows parallel to the interface of the valley and the rise, complex patterns are observed. Data on this type of flow are not sufficient in the literature to clearly define these patterns.

These types of flow patterns have significant impact on the dispersion of stack plumes. For flows from the south-east quadrants, large eddies comparable in size to the height of the escarpment are expected to form. These eddies will enhance the vertical diffusion of the plume and the accelerating flow at the escarpment will limit the plume rise. The stack plume caught in north-west flows will descend towards the plume rise, thereby affecting the vertical dispersion.

The above pattern of plume dispersion is expected to be typical of high wind situations. For low winds and strong solar insolation, a convective boundary layer forms. Such a boundary layer, which is often called the mixed layer, is characterized by a surface shear zone up to a height approximately equal to Obukhov length $|L|$*, a free convection layer from $|L|$ to about 1/10th the height of the boundary layer Zi, and a mixed layer from 0.1Zi to Zi. Within the mixed layer matter, energy and momentum transfer take place by large-scale and long-lived eddies (often called up-drafts and down-drafts). These eddies break up the pollutant plume, fast mixing it in the vertical within a short down-wind distance from the stack. In the early morning hours when the mixed layer is growing, a potential problem of plume trapping exists.

The dispersion characteristics within the mixed layer are studied by a convective velocity scale, W*, defined as

$$\left[\frac{gH_0Z_i}{\rho C_p T}\right]^{\frac{1}{3}} \qquad (4.1)$$

where g is the acceleration due to gravity, H_0 is the surface heat flux, T is an average mixed layer temperature, ρ is the density of air and C_p the specific heat at constant pressure.

The ratio V/W*, where V is the average mixed layer wind, determines the extent to which the mixed layer is convective. When V/W*   6, the bulk of the mixed layer is dominated by convective turbulence with little influence of shear production of turbulent energy.

The above description of the characteristics of flow at Falconbridge suggests the following scenarios when high ground level concentrations are expected to occur.

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* Obukhov length L is defined by taking the ratio of shear to heat convection production of turbulent energy. A large $|L|$ implies strong shear and a small $|L|$ strong convection. The Obukhov length may be either positive or negative.

4.2 SCENARIOS FOR HIGH GROUND LEVEL CONCENTRATION

4.2.1 Light Winds with South-East Component

The configuration of the stack relative to the ground level for this type of flow is depicted in Figure 69. When the mixed layer is developed in the early morning hours, there is a potential for plume trapping for mixed layer heights of the order of 100 to 200 meters. This generally occurs during the period from 800 to 1200. As the day progresses, increased solar radiation causes the mixed layer to grow higher, thereby causing the ground level concentrations (which are inversely proportional to the mixed layer height) to become smaller for the same down-wind distance. Occasional plume looping and plume touch-down causing short-term high ground level concentrations might occur after 1200. For Zi greater than 1,000 meters (which is typically the case at Falconbridge during spring and summer months during midday), the stack plume is less subject to the tearing action of the large eddies, and is dispersed by small scale eddies.

Sporadic excursion to high concentration is not critical since we are interested in the half-hour and one-hour average concentrations.

It would appear, therefore, that the most probable period of exceedance under these meteorological conditions is from 800 to 1200. This case may occur, however, at any time when the boundary layer is convective and when the boundary layer height is less than 1,000 meters.

4.2.2 Light Winds with North-West Component

Under these conditions, the flow is from the escarpment top towards the valley as shown in Figure 70. From the valley floor the effective stack height is approximately 150 meters.

During the clear day-time periods of spring and summer, therefore, the stack behaves as a tall stack whose plume is subjected to the tearing action of the large eddies of the convective boundary layer. This is because the maximum mixed layer height is of the order of 2,000 meters at Falconbridge.

The plume will follow the streamlines as it traverses the valley, thereby sinking with the streamlines and resulting in low plume rise. In the early morning hours, plume trapping will occur, followed by plume looping as the day progresses.

It appears, therefore, that for these situations the most probable period of exceedance is from 700 to 1800.

4.2.3 High Winds

High wind conditions are defined, for this report, for mean wind speeds greater than 7 ms^{-1}. The plausible flow patterns in these cases are depicted in Figure 71. Large mechanical eddies are expected to form in this case, which will inhibit plume rise while breaking it up in a manner similar to the large eddies of the convective boundary layer. This is expected to result in high ground level concentrations.

Most high wind cases occur during winter months at Falconbridge, when a ground based temperature inversion is normally observed. High winds will create a shallow mechanical mixed layer which will also limit the vertical mixing of the plume.

Thus, all high wind conditions are critical.

4.2.4 Other Conditions

The other conditions are defined as other plausible meteorological conditions not covered in the above three scenarios. These will occur, for instance, when light wind neutral boundary layers form. Under these conditions, the plume is expected to disperse due to small eddies formed by mechanical turbulence. The uneven topography of Falconbridge will enhance vertical diffusion.

As a rule of thumb, the maximum ground level concentrations occur when the vertical standard deviation of the plume, σ_z, is equal to h/1.414, where h is the effective plume height. The effective plume height is equal to the sum of the stack height and the plume rise. Unlike the previous three scenarios, the plume rise will be significant for these cases.

Some exceedances are likely to occur for these cases since the stack height is very small. The frequency of occurrence of these exceedances is not expected to be very high.

4.3 CLASSIFICATION OF FIELD STUDY EXCEEDANCES

During the two months of the Falconbridge field study, there were 56 observed exceedances of either the half-hour ground level concentration standard or the one-hour ground level criterion. Except for two cases which were measured early in the morning on June 22 at the Skead monitor, all observed exceedances have been summarized on Table 28. These exceedances will now be categorized according to the scenarios described above.

Applying the limit of $7 ms^{-1}$ to define windy cases, eight of the 54 recorded exceedances could be classified as high winds exceedances. Three of these cases also satisfy the definition for a convective boundary layer.

Of the remaining 46 exceedances, 36 are convective cases ($V/W^* < 6$), with five observed at sites to the south of the Falconbridge plant. The other 31 cases are monitored at locations west or north of the Plant. The 31 cases which may be categorized as being associated with light winds with a south-east component all occurred between 700 and 1200, with two exceptions which occurred between 1300 and 1400. Four of the five exceedances observed south of the plant were monitored between 800 and 1100 and the other exceedances occurred between 1600 and 1700.

Based on the criteria set for categorizing the exceedance, ten cases are neither convective nor high-wind-scenarios. Six of these high concentration periods were recorded on June 9, 1983. This day was overcast and moderately windy. These exceedances were observed at the MTC garage which is separated from Falconbridge Plant by approximately 3.5 kilometers. These cases may represent the neutral dispersion case described in Section 4.2.4.

The other four non-convective, low wind exceedances occurred on May 13th and June 28th and fell just above the limit of $V/W^* < 6$, thereby suggesting that these cases may be due to composite of turbulence generated by convection and by shear stress.

4.4 CLASSIFICATION OF HISTORICAL EXCEEDANCES

All exceedances of the one-hour criterion of ground level SO_2 concentration (.25 ppm) at the Coniston and Skead fixed monitors since July 15, 1978 have been reviewed in terms of the guidelines for classification discussed in Section 4.2. All cases without associated wind data were filtered from the data set. The data was also checked to ensure (as best as possible) that exceedances were, in fact, due to the Falconbridge plume. In order to monitor direction within a window of plus/minus 60°, the criterion used was correspondence of wind direction to the stack. After removing data which did not satisfy this restriction, there remained 75 exceedances at the Coniston monitor and 226 at the Skead monitor.

Skead is located approximately 10.5 kilometers north-north-east of the Falconbridge plant. Winds associated with exceedances at the Skead receptor blow from the southerly sector. 82 of these Skead exceedances occurred during the summer (April to October inclusive) in the day-time when convective conditions may potentially occur. Based on a limit of 7 ms^{-1} to define high wind cases, 28 (or 34%) of the 82 exceedances can be classified in the windy category. Thus, 24% (or 54) of the 226 exceedances at the Skead receptor may be convective, low wind scenario.

If, however, the windy criterion were 10 ms^{-1}, then 10 of the summer day-time exceedances would be classified as high wind cases and 72 (or 32%) of the total Skead exceedances would be in the convective low wind category.

Figure 72 presents a histogram of the distributions of the Skead summer-day cases. It is not possible to determine whether the low wind day-time cases occurred under convective conditions. Figure 72 presents a histogram of the frequency of these exceedances (winds $<$ 7 ms^{-1}) grouped by the time of day the high concentration occurred. The greatest number of day-time exceedances occurred around the noon hour, when the solar insolation is usually the greatest and a convective mixed layer would be expected.

Using 7 ms^{-1} as the criterion for classifying exceedances as high wind cases, 117 cases (or 52%) of the 226 exceedances would be categorized as windy both day and night. Dividing the windy cases between seasons results in 41% of the exceedances occurring in the five winter months and 59% in the seven summer months.

11 summer night-time cases and 41 winter-time cases do not satisfy the windy ($<$7 ms^{-1}) criterion. These cases, therefore, would be covered by "other conditions" described in Section 4.2.4. Figure 74 presents wind speed histograms for the summer night and winter exceedances.

The Coniston monitor is approximately 10.5 kilometers south-south-east of the Falconbridge plant. For the period reviewed, 36 (or 48%) of the 75 exceedances occurred during summer days and four of these cases occurred when the wind speed was greater than 7 ms^{-1}. Hence, approximately 42% of the Coniston exceedances may be low-wind convection cases. (Other scenarios for these exceedances cannot, however, be ruled out.) Figure 75 presents wind histograms for the summer day-time exceedances using both wind speed criteria (7 ms^{-1} and 10 ms^{-1}). Figure 76 indicates that the time distribution is centred on the noon hour.

Summer night-time exceedances attributable to the Falconbridge Plant were recorded at the Coniston monitor only four times during the period analyzed, all of which occurred when the wind speeds were greater than 7 ms^{-1}. 47% of the Coniston exceedances occurred during the five winter months. As 10 of these 35 exceedances occurred under windy conditions ($>$7 ms^{-1}), at least one-third of the exceedances at Coniston do not fit into either the convective or the windy classifications. Figure 77 presents a wind histogram and a time histogram of the winter-time exceedances. The time histogram (for winds $<$7 ms^{-1}) reveals that the majority of exceedances occurred between 1000 and 1600, thereby suggesting that solar input and, perhaps, convection, may be important in winter-time exceedances.

5.0 FEASIBILITY OF SUPPLEMENTARY CONTROL

5.1 DEFINITION

Supplementary control refers to source control during unfavourable meteorological conditions, preventing exceedances of SO_2 criteria at the ground level. Implied is that the frequency with which the observed ground level concentrations exceed the criteria is small, making the institution of a supplementary control system feasible.

For the purpose of this report, we shall refer to exceedances as ground level SO_2 concentration (averaged over half-hour periods) in excess of .3 ppm anywhere within the area surrounding the Falconbridge smelter. Such an exceedance would have to be conclusively attributable to Falconbridge smelter in order that supplementary control system becomes effective.

Several methods are used in a supplementary control system. At Ontario Hydro's Lakeview generating station, the control is based mostly on meteorology. A different mixture of coal with a lower net sulphur content is used when the winds are on-shore. For Inco, Sudbury and Algoma Steel, Wawa, the supplementary control systems employ dispersion models and air quality monitoring.

It is clear from the above examples of supplementary control systems that the feasibility of instituting such a system depends on the frequency of exceedances and on the potentiality of developing dispersion models for the meteorological conditions which are responsible for these exceedances.

In this section, we shall present an analysis of the exceedances, the nature of meteorology during these exceedances, and the feasibility of modelling the dispersion of effluents from the Falconbridge stack during these meteorological conditions.

5.2 FREQUENCY OF HIGH GROUND LEVEL CONCENTRATION

The distribution of the 54 exceedances measured during the May and June 1983 Falconbridge field study may be summarized as follows:

- 31 convective cases with light winds from a southerly direction
- 5 convective cases with light winds from a northerly direction
- 8 high wind cases (>7 ms^{-1})
- 10 cases not belonging to the three categories above

This distribution must not, however, be viewed out of context from the limitations of the field study. For example, the mobile monitors were restricted in their site selection due to sparcity of roads around the Falconbridge Plant. The study period was short and, as a result, surveyed only a limited set of meteorological conditions.

The most noteworthy result of the survey is the large number of cases dominated by convection (67% of the exceedances), thereby suggesting that fumigation of the Falconbridge plume may account for a significant portion of the high SO_2 ground level concentration measurements recorded in this area.

Historic data presented in Section 4.4 considered exceedances over 0.25 ppm for one hour average ground level concentrations and was limited to only the Coniston and Skead monitors, both more than 10 kilometers from the Falconbridge Plant. Thus, the historic data analysis is very restrictive in its geographic coverage. It is, however, presented to further substantiate our hypotheses of the meteorological conditions which lead to high ground level concentrations attributed to Falconbridge smelter plume.

South of the Falconbridge plant (at Coniston), the 75 exceedances may be summarized as follows:

- 32 summer day-time cases with light winds from a northerly direction
- 18 high wind cases
- 25 cases not clearly belonging to either category above

Although not all of the 32 summer day-time exceedances necessarily occurred under convective conditions, it is reasonable to assume that a significant number of them did so.

North of the Plant at Skead, the 226 exceedances may be classified as follows:

- 54 summer day-time cases with light winds from a southerly direction
- 107 high wind cases
- 65 cases not clearly belonging to either category above

Based on these statistics, it appears that a large number of the high concentration incidents due to Falconbridge emissions can be classified as either convective or high wind cases (approximately 81% of the total field study recorded exceedances, an estimated 71% of the exceedances at Skead and 67% of the exceedances at Coniston).

5.3 FEASIBILITY OF MODELLING HIGH GROUND LEVEL CONCENTRATIONS

Following are the scenarios which have been identified as contributors to high ground level concentrations in the sectors of interest around Falconbridge smelter stack.

- morning plume trapping
- convective plume fumigation in southern quadrant
- high wind conditions
- other (e.g. neutral dispersion)

5.3.1 Morning Trapping (Light winds with south-easterly component)

To establish whether the hypothesis of the morning trapping scenario is correct, it was assumed that the dispersion conditions during the period from 800 to 1200 for sunny skies in spring, summer and fall were in step-wise steady state. In other words, even though the boundary layer height was rapidly rising during this period, a one-hour segment would be in a quasi-steady state. Thus it can be assumed that the plume will be well mixed in the vertical rapidly. Based on this assumption and utilizing mixed layer scaling, the following formula for plume dispersion was derived:

$$\frac{C}{Q} = \frac{1}{\sqrt{2\pi}\;\sigma_y\, Z_i\, V} \exp\left[-\frac{y^2}{2\,\sigma_y{}^2}\right] \qquad (5.1)$$

$$\sigma_y = 0.45\,\frac{W^*}{V}\,X$$

where the variables have been previously derived in Section 4. Q is the stack emission rate.

The above formula was compared with observed ground level concentrations.

The cross wind distance y was estimated to be small, which implicitly assumes that the mean path of the plume was directly toward the monitor during the period of the exceedance. If $\overline{X}$ is defined as: XW^*/VZ_i, it is possible to write equation (5.1) as

$$\overline{C} = \frac{CZi^2V}{Q} = .9/\overline{X} \qquad (5.2)$$

Table 29 summarizes the exceedances observed during the field study which according to the criteria described in Section 4, are morning trapping cases. In order to satisfy the vertically well mixed criteria, only those exceedances occurring at distances greater than X=3.0 have been included in Table 29. [Closer to the stack equation (5.2) may still match the observations and a limit of $\overline{X}$=1.0 is sometimes used. However, for this analysis the limit of 3.0 recommended by Venkatram (Atmos. Envir., 14, pp 1-10, 1980) will be used.]

TABLE 29

NON-DIMENSIONAL CONCENTRATION AND DOWN-WIND DISTANCE FOR EXCEEDANCE MEETING THE MORNING TRAPPING CRITERIA AND THE WELL-MIXED CONDITION

(CALCULATED ACCORDING TO EQUATION 5.2)

Date	Time	$\bar{X}$	$\bar{C}$
May 11	1000-1100	3.68	.82
May 11	955-1025	3.68	.36
May 13	900-1000	31.79	.01
May 13	900- 930	33.88	.004
May 13	930-1000	30.50	.01
May 13	1000-1030	19.57	.01
May 13	1000-1030	16.45	.01
May 13	1120-1150	8.66	.07
May 31	1025-1125	5.02	.09
May 31	1030-1100	3.49	.11
May 31	1230-1330	3.37	.54
June 20	1010-1040	7.61	.04
June 21	1000-1100	10.07	.12
June 21	1000-1030	10.32	.05
June 21	1030-1100	9.98	.07
June 21	1130-1230	4.79	.41
June 21	1130-1200	6.06	.17
June 21	1130-1200	6.19	.13

Average $1/\bar{X} = .15$

Average $\bar{C} = .17$

Figure 78 presents a comparison of $1/\overline{X}$ and the non-dimensional concentration $\overline{C}$ for the data in Table 29. The solid dark line defines the (least-squares) best linear fit to the data and the dashed line presents the best fit line constrained to pass through the origin (i.e. $\overline{C}$ goes to zero as $\overline{X}$ becomes very large). The slope of the dashed line is 1.2 which, when the uncertainties in the model parameters (i.e. the height of the mixed layer) are considered, is not substantially different than the proposed value of .9.

The correspondence of $\overline{C}$ and $1/\overline{X}$ is tested using the linear correlation coefficient squared (R^2) which, for the 18 data points plotted in Figure 78, is approximately 0.6. Significant correlation between the inverse of the non-dimensional distance $\overline{X}$ and the non-dimensional concentration $\overline{C}$ is indicated. Given that the criteria of morning trapping are met, therefore, it is possible to estimate concentration once the atmospheric boundary layer parameters are known. For example, if the mixed layer height is 500 m and W^* is .8 ms^{-1}, then SO_2 emissions must be approximately 3.0 tonnes/hour or less to avoid exceeding the one-hour criterion of .25 ppm.

It is noted that equation 5.1 does not correctly account for initial dispersion. Thus, using 5.1 for near field glc would introduce large errors. Several methods currently exist to account for this initial dispersion. The models developed by Venkatram (1981), Lamb (1979), Misra (1982) are examples. It is clear, however, that this condition can be modelled reasonably accurately.

5.3.2 Light Winds with North-westerly Component

Too few exceedances belonging to this category were recorded during the two-month study period to permit the testing of any hypotheses regarding high concentration episodes falling into this classification. Only three cases were measured south of the Plant but outside the Happy Valley area. This is due, in part, to the lack of road access to the region south of the Falconbridge plant.

It is expected that the modelling described in Section 5.3.1 may be applied to these cases.

5.3.3 Windy Conditions

Windy conditions imply mechanically mixing due to shear-generated turbulence. Rough terrain, such as exists in the Sudbury area, will result in a complex relationship between plume mixing and the surface topography.

Under neutral conditions, high winds will generate large eddies which will be mainly responsible for the plume dispersion. Not much is known about the characteristics of the large eddies, particularly for complex topography. Under stable conditions, high winds will be responsible for the establishment of a shallow mixed layer. The plume is expected to be trapped in this mixed layer as in morning hours of scenario 1, pointing to the fact that physical modelling in wind tunnels may be necessary to develop suitable models for the high wind cases.

5.3.4 Other Conditions

For stable and neutral atmospheric conditions, it can be assumed that the maximum ground level concentrations are observed where $_{z}$ equals h/1.414 - h being the height of the stack. If we assume a Gaussian plume for these conditions, then

$$\frac{C}{Q} = \frac{1}{\sqrt{2\pi}\;\sigma_y\;\sigma_z\;u}\quad \exp\left[-\frac{h^2}{2\,\sigma_z^2}\right] \qquad (5.3)$$

where C is the centre line concentration.

Since $\sigma_z = h/1.414$ for the maximum ground level concentration and assuming $\sigma_y = \alpha\,\sigma_z$, equation 5.3 gives the following.

$$\frac{C_{max}}{Q} = \frac{0.8}{\alpha h^2 U} \exp\left[- 1 \right] \qquad (5.4)$$

$$= \frac{0.294}{\alpha h^2 U}$$

If we require that C_{max} is always less than .25 ppm ($\sim$ 50 μgm^{-3}) averaged over a one-hour period, then

$$\frac{Q}{h^2 U} < \alpha (2.2 \times 10^{-6}) \qquad (4.6)$$

where Q is expressed in Kg s^{-1}.

The factor α is typically of the order 2 but can be as high as 6. This implies that, when Q is greater than about 1 Kg s^{-1} (3.6 tonnes per hour), there is a potential for exceedance of the criteria glc in neutral and stable atmospheric conditions.

5.4 FEASIBILITY OF SUPPLEMENTARY CONTROL

Intermittent control requires that the periods of high ground level concentrations be correlated with identifiable sets of conditions. During the two months of the Falconbridge field study, three possible scenarios for high concentrations were observed:

- light winds with a south-easterly component during morning periods (morning trapping of the plume)
- light winds with a north-westerly component during day-time periods
- windy periods

The feasibility of controlling emissions in order to reduce the occurrence of high ground level concentrations during these periods will depend on the frequency of these meteorological conditions.

Figure 79 presents the estimated frequency with which windy periods (winds greater than 7 ms^{-1}) and light winds with potentially convective conditions have occurred during the years 1975 through August 1983 in the four quadrants surrounding the Falconbridge Plant. The frequencies are reported as hour per month and total hours per year. North of the Plant, Based on the 7½ years of meteorological data, it is estimated that winds exceeding 7 ms^{-1} blowing into this sector would occur approximately 680 hours per year. West of the Plant, high winds ($>$ 7 ms^{-1}) blow from the direction of the Falconbridge stack approximately 150 hours per year and south of the Plant, the frequency of high winds (from the north) is approximately 1,087 hours per year. These three sectors include the major population regions adjacent to the Plant. Therefore, if windy conditions (with wind speeds greater than 7 ms^{-1}) are used as a criterion for emission abatement, then emissions would need to be controlled for approximately 1,917 hours per year (22% of the year). During the two-month field study, insufficient high wind cases were monitored to clearly define any limiting wind speed for "windy" exceedances. The figure of 7 ms^{-1} has been choosen based on our knowledge of the planetary boundary layers. This can be refined with more site specific data.

The majority of the exceedances recorded during the field study were due to convective mixing (38 of the 54 cases had $V/W^* < 6$). Also, all of the observed exceedances occurred when the mixed layer height was estimated to be 900 meters or less. Based on the history of meteorological data, potentially convective conditions during light winds occurred approximately 1,360 hours per year (or 16% of the year) in the three sectors of interest as shown in Figure 79. Assuming that a limited mixed layer height (i.e. less than 1,000 meters) is also a criterion for exceedances under convective conditions (plume trapping) in sectors to the north and west of the Plant, then the number of hours requiring control decreases from 826 in these sectors (Figure 79) to approximately 610.

Analysis of the field study data and the historical air quality data from Skead and Coniston indicates that 81% of the field study cases and approximately 70% of the historic exceedances were associated either with windy conditions ($V > 7\ ms^{-1}$) or with light winds and potentially convective conditions. The data reveals that, under these conditions, exceedances occur approximately 38% of the time.

Dispersion under neutral conditions has been proposed as a fourth scenario for exceedances. While it is possible that several of the historical high ground level concentration periods are associated with neutral boundary layer, there may be, however, alternative methods of classifying the observed exceedances. No projections about feasibility of supplementary control can be made for these cases within the context of this study.

6.0 CONCLUSIONS AND RECOMMENDATIONS

There were 56 exceedances of either the one-hour criterion for SO_2 ground level concentrations of .25 ppm or the half-hour standard of .30 ppm recorded in the Falconbridge study area during the field survey. 54 of these cases were clearly identified as being due to the Falconbridge plume. Approximately 80% of these exceedances occurred under convective conditions and all exceedances were associated with limited vertical mixing depths. Specifically, the mixed layer height was estimated to be only 900 meters or less for all of the observed exceedances.

In Section 5.3.1, a model was proposed for estimating the average (ground level) concentration due to a convectively mixed plume trapped in a boundary layer which is relatively shallow with respect to the stack height. Testing this model with the field survey data suggests that modelling of exceedances of this type may be feasible.

Three other possible conditions associated with high ground level concentration have been proposed in this report:

1. Windy conditions, defined as winds greater than 7 ms^{-1}, were observed during eight of the exceedances recorded during the field study. A review of historic exceedances at MOE monitoring sites in the Falconbridge area indicates, however, that a relatively large number of exceedances occurred under windy conditions, particularly in the winter and at night. No conclusions can be drawn from the small sample of windy cases recorded during the Falconbridge field study. It is recommended that a study of high SO_2 ground level concentrations specifically due to Falconbridge emissions under windy conditions be conducted.

2. Dispersion under neutral conditions was also proposed as a plausible scenario for high ground level concentrations and a model for estimating maximum average concentrations has been described (Section 5.3.4). During the May and June 1983 field study, only

six exceedances occurred when the conditions could be classified as nearly neutral (excluding windy cases). Further study during neutral conditions is recommended.

3. Five exceedances were recorded south of the Falconbridge Plant during the field study. Although data is insufficient to propose modelling, all of these cases were, in fact, associated with light wind, convective conditions. Further data collection for high concentration episodes south of the plant is recommended.

Analysis of the frequency of exceedances (.3 ppm over half-hour) suggests that intermittent control would be required (on average) less than 40% of the time, thereby significantly reducing the number of ground level exceedances. Control under convective conditions with light winds and limited vertical mixing appears to be feasible and would require collection of meteorological data, specifically a 100-meter meteorological tower in the vicinity of the Falconbridge plant (but not in the Valley) to monitor winds and temperature at two or more vertical levels; a minisonde system for determining mixed layer heights; and a method of determining the net solar radiation.

Criteria of controlling under "other conditions" should also be reviewed. To aid in this review, increased air quality monitoring in the Falconbridge region by dedicated mobile vans and/or additional fixed location monitors is recommended. Mobile monitoring should begin at sun-rise during the non-snow covered seasons.

Half-hour average SO_2 emission rates measured in the plant stack were compared with the calculated half-hour average emissions. On average, the calculated emissions were found to slightly over-estimate the measured emissions. The notable exception was when the emissions were very large (greater than 10.0 tonnes per half-hour), in which cases the calculated emissions under-estimated the measured emissions. It is recommended that SO_2 emissions be recorded at all times when the plant is operating.

While reviewing the emissions during exceedance periods, it was noted that more than 36% of the recorded exceedances occurred either when the roaster gases were being directed to the stack (by-passing the acid plant) or when two converters were operating simultaneously. The feasibility of scheduling plant activities around periods when meteorological conditions favour high ground level concentrations appears to be worth consideration.

Further study of the data set from the Falconbridge survey will be continuing and will be expanded to include the data of non-exceedance cases not considered in this report.

Based on the findings of this report, it is concluded that a supplementary control system for Falconbridge smelter is feasible without severely jeopardizing the plant operation.

REFERENCES

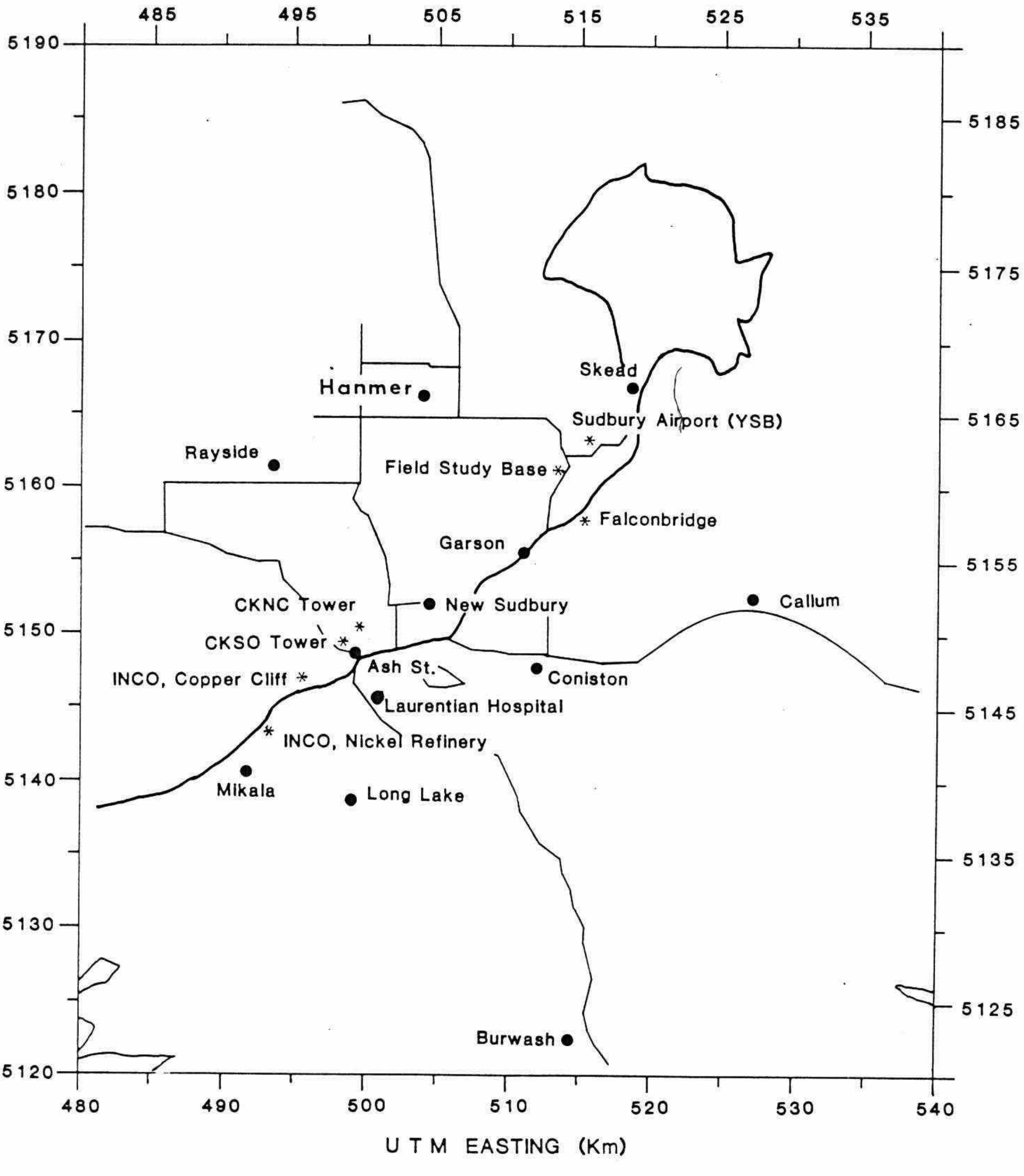
Kurtz, J; (1982): Internal Memorandum. Air Resources Branch, Ontario Ministry of Environment.

Lamb, R.G.; (1978): "A numerical simulation of dispersion from a elevated point source in the convective planetary boundary layer." Atmos. Envir., 12, pp 1,297-1,304.

Misra, P.K.; (1982): "Dispersion of Non-Buoyant Particles Inside a Convective Boundary Layer." Atmos. Envir., 16, pp 239-243.

Venkatram, A; (1980): "Disperson from an elevated source in a convective boundary layer." Atmos. Envir., 14, pp 1-10.

FIGURE 1



SUDBURY AREA SHOWING PERMANENT MONITORS,
MET OBSERVATION LOCATIONS AND STACK LOCATIONS

FIGURE 2

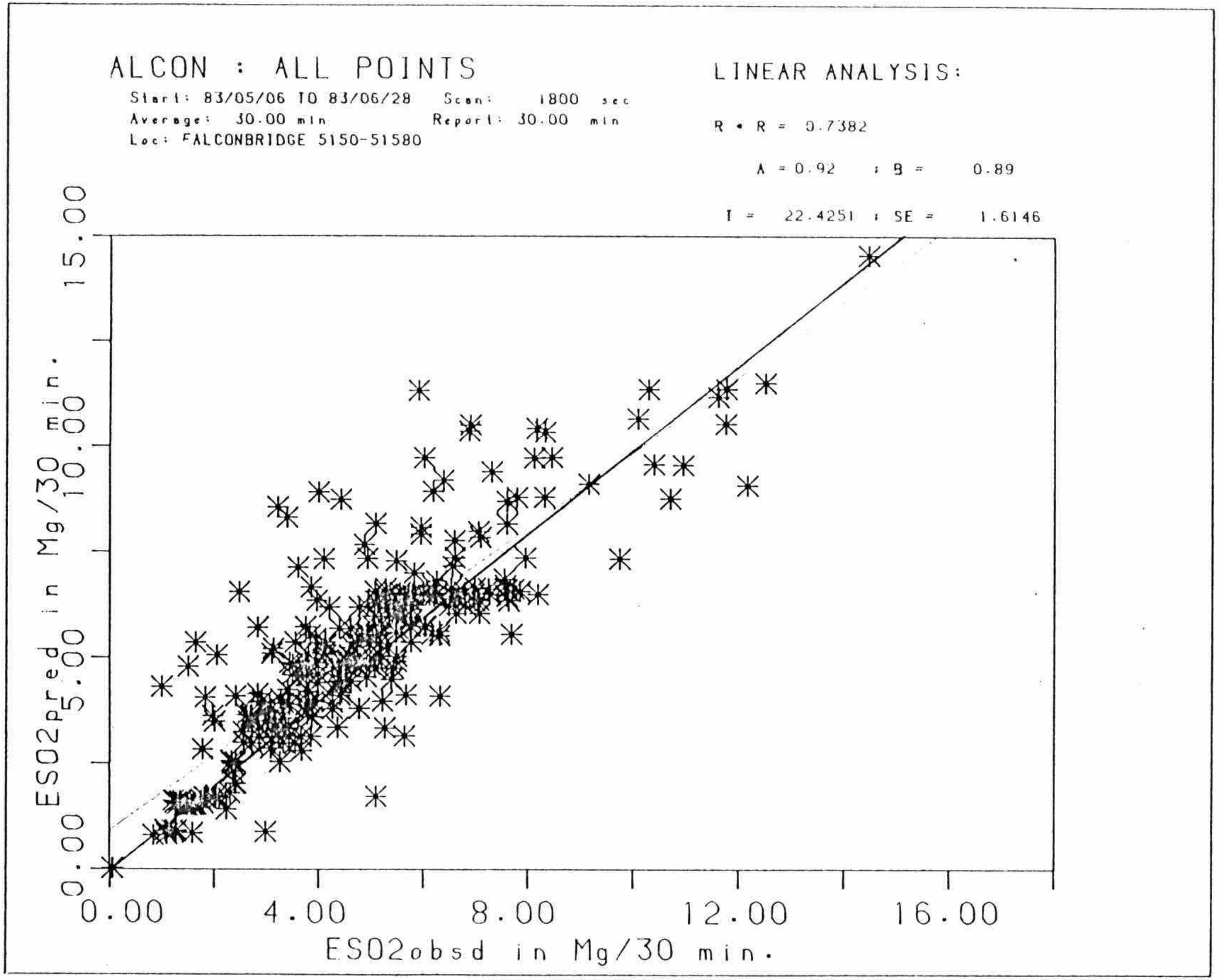
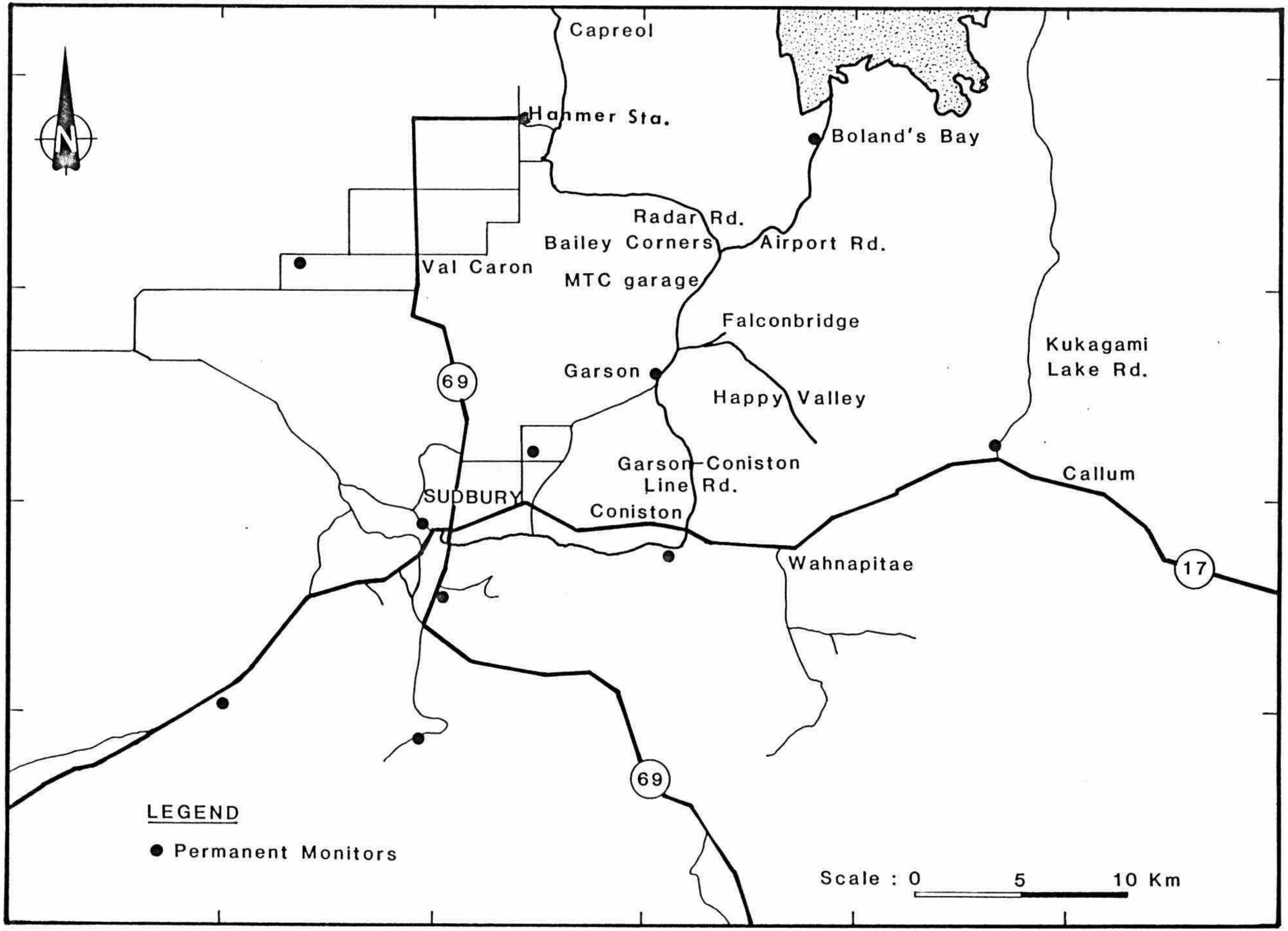
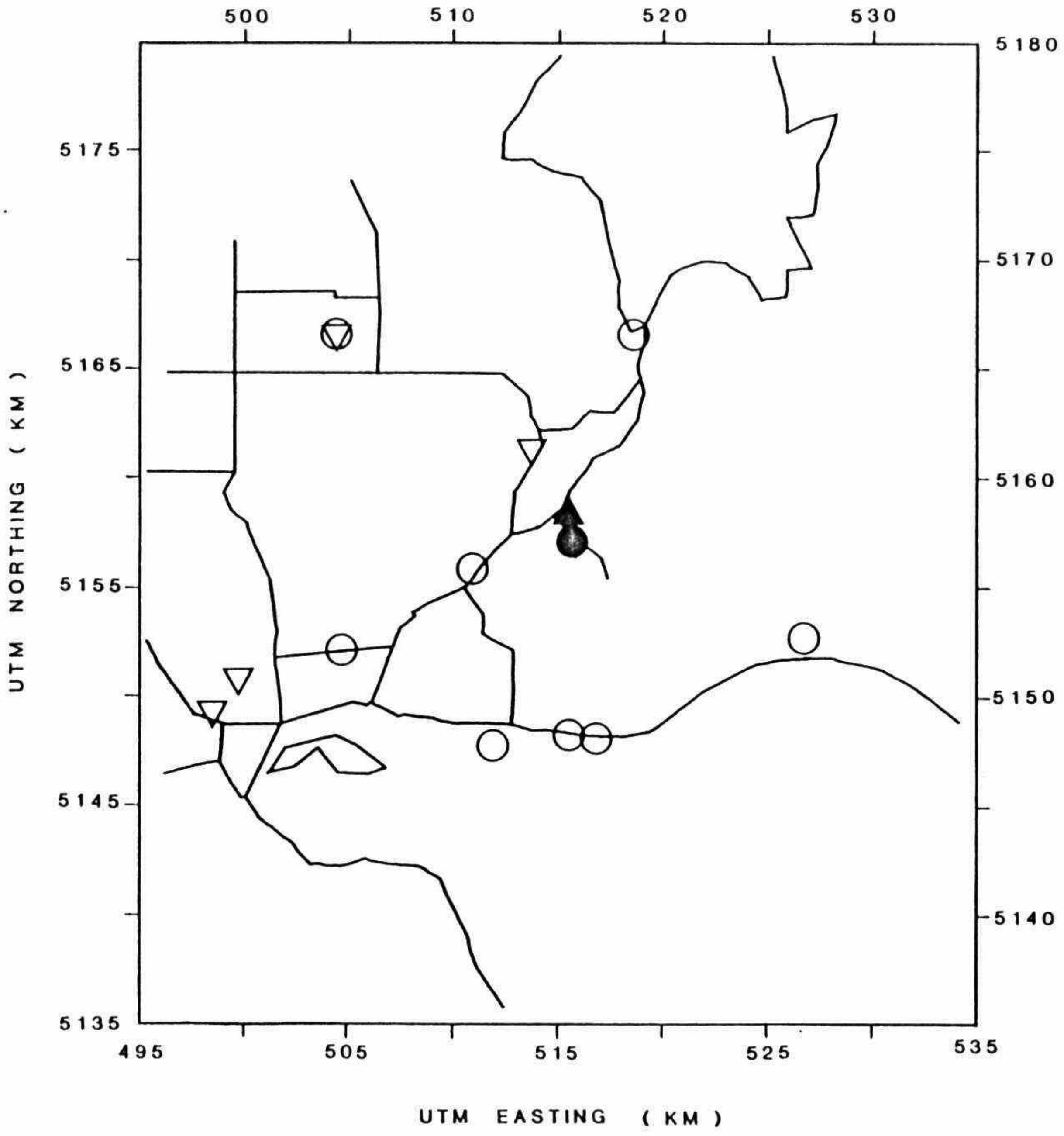

ALCON : ALL POINTS
Start: 83/05/06 TO 83/06/28 Scan: 1800 sec
Average: 30.00 min Report: 30.00 min
Loc: FALCONBRIDGE 5150-51580
LINEAR ANALYSIS:
R * R = 0.7382
A = 0.92 ; B = 0.89
T = 22.4251 ; SE = 1.6146
0.00
5.00
10.00
15.00
ESO2pred in Mg/30 min.
0.00
4.00
8.00
12.00
16.00
ESO2obsd in Mg/30 min.

FIGURE 3



LOCATIONS OF PERMANENT MONITORS

FIGURE 4



MEASURED EXCEEDENCES

MAY 5, 1983

1/2 Hr. Standard:
Site 1 (MAMU 1) 1000-1030 :30 ppm

1 Hr. Criterion:
no exceedences measured

SYMBOLS:

○ SO_2 monitors (fixed or mobile)
▲ Falconbridge
▽ Met. stations (including MTC garage)
● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion
▼ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 5

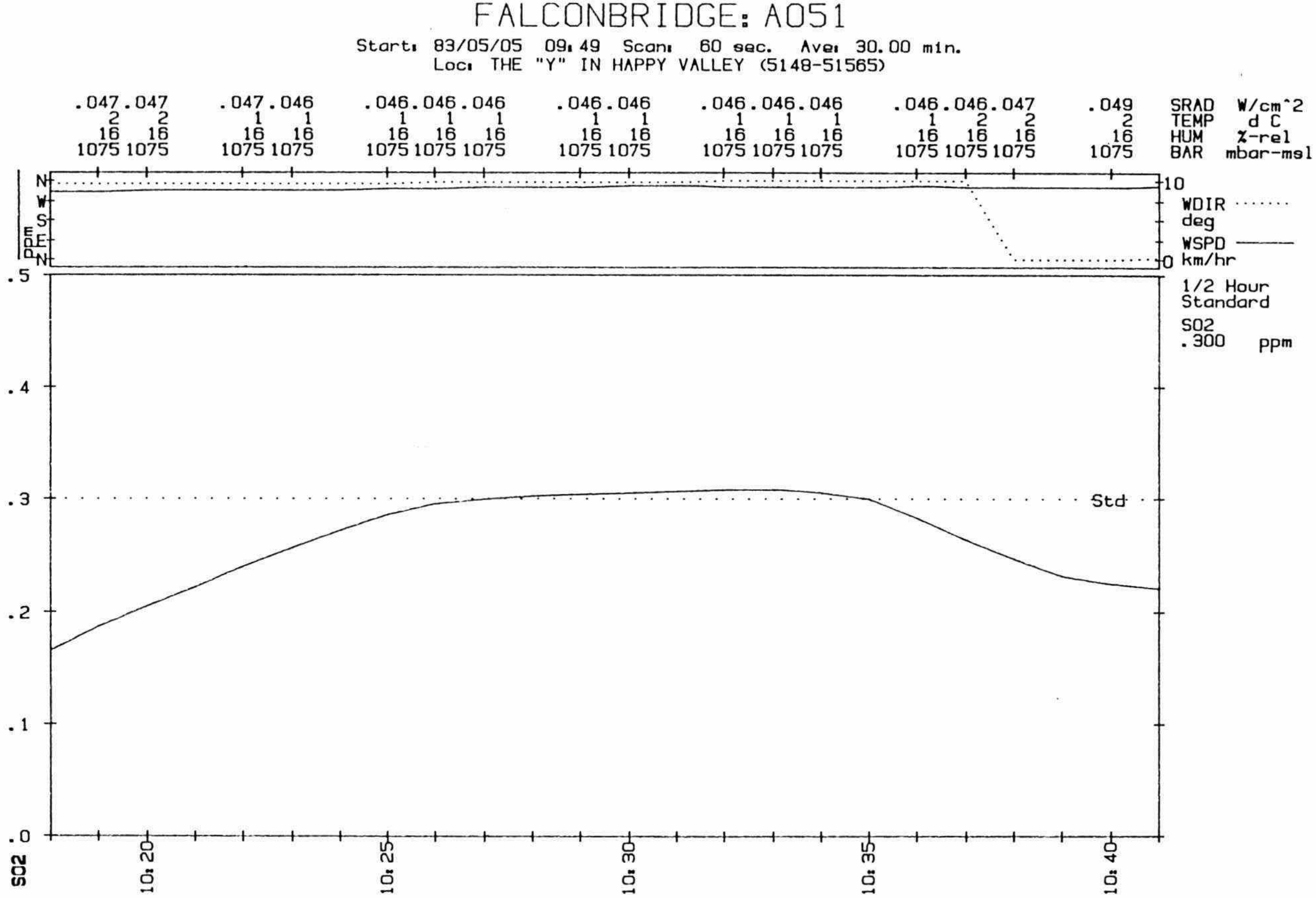
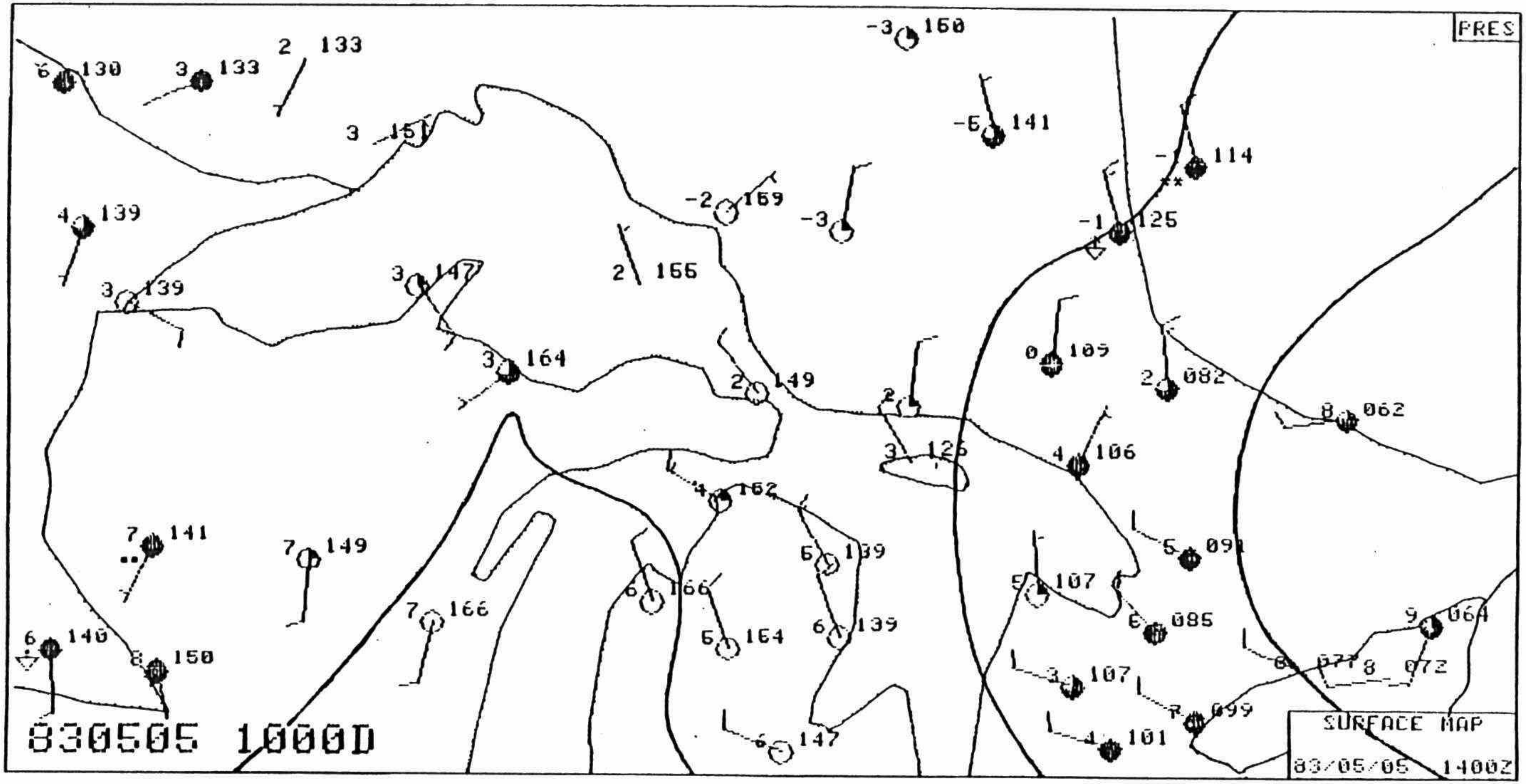

FALCONBRIDGE: A051
Start: 83/05/05 09:49 Scan: 60 sec. Ave: 30.00 min.
Loc: THE "Y" IN HAPPY VALLEY (5148-51565)
.047 .047 .047 .046 .046 .046 .046 .046 .046 .046 .046 .046 .046 .046 .047 .049
2 2 1 1 1 1 1 1 1 1 1 1 1 2 2 2
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
1075 1075 1075 1075 1075 1075 1075 1075 1075 1075 1075 1075 1075 1075 1075 1075
SRAD W/cm^2
TEMP d C
HUM %-rel
BAR mbar-msl
N
W
S
E
N
mph
10
WDIR ......
deg
WSPD ——
0 km/hr
1/2 Hour Standard
SO2 .300 ppm
Std
.5
.4
.3
.2
.1
.0
SO2
10:20
10:25
10:30
10:35
10:40

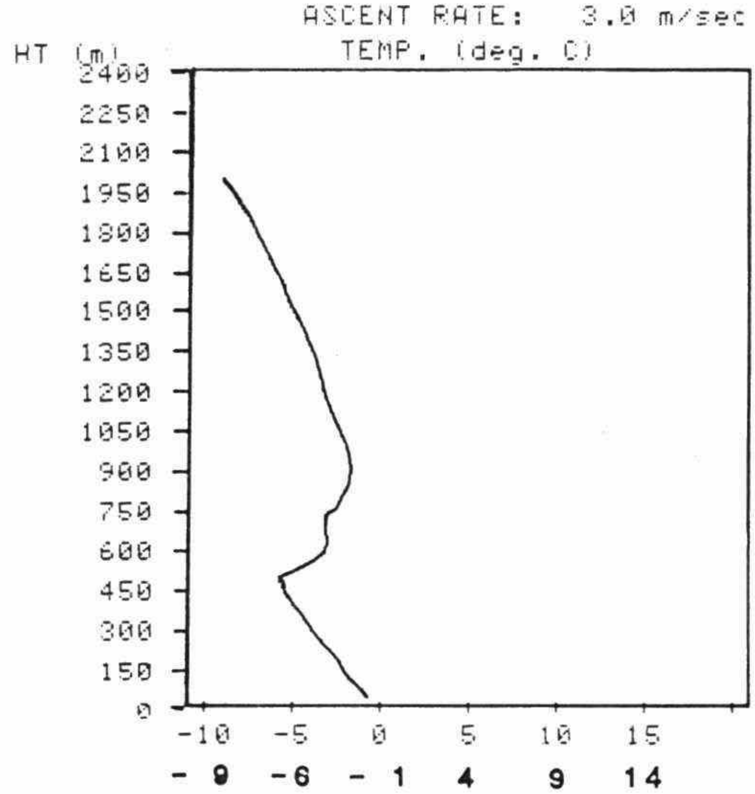
FIGURE 6



SURFACE WEATHER MAP AT 1400Z, MAY 5, 1983.

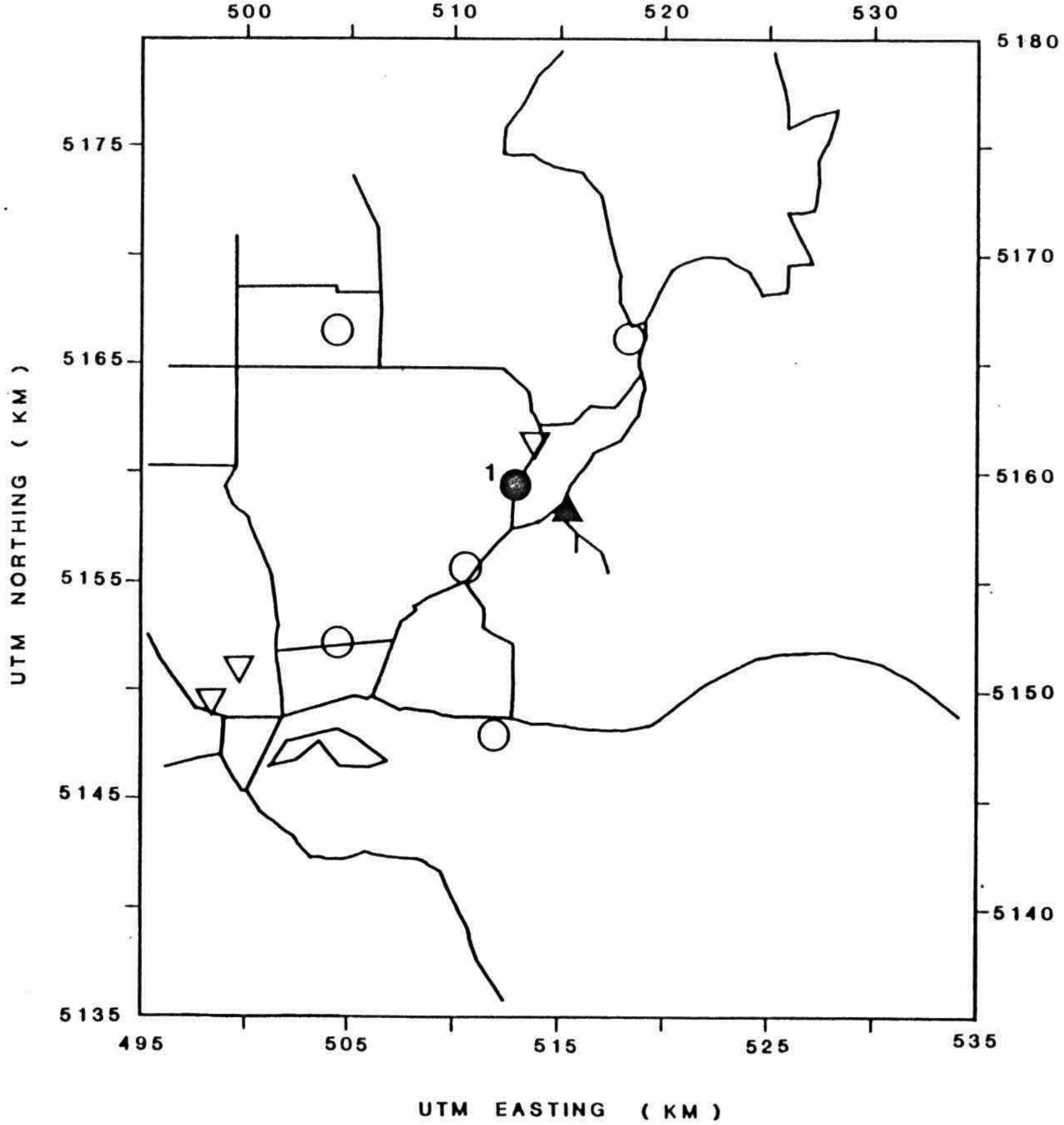
FIGURE 7

TEMPERATURE PROFILE WITH HEIGHT, MAY 5, 1983.



```
NAME: FALCONBRIDGE_UA:M051A
LOC:  GARAGE
MET:  CU BRISK NORTHERLY WINDS
ELEV:       1000.0 m.
BASE:        100.0 m.                       GND TEMP:    -.0 deg.C ( -1°C )
                                            BEARING : 126.0 deg.
```

FIGURE 8



MEASURED EXCEEDENCES

MAY 11, 1983

1/2 Hr. Standard:

Site 1	**(MAMU 2)**	**0955-1025**	**.67 ppm**
Site 1	**(MAMU 2)**	**1025-1155**	**.61 ppm**
Site 1	**(MAMU 2)**	**1055-1155**	**.35 ppm**

1 Hr. Criterion:

Site 1	**(MAMU 2)**	**1000-1100**	**.66 ppm**

SYMBOLS:

○ SO_2 monitors (fixed or mobile)

▲ Falconbridge

▽ Met. stations (including MTC garage)

● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion

▼ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 9

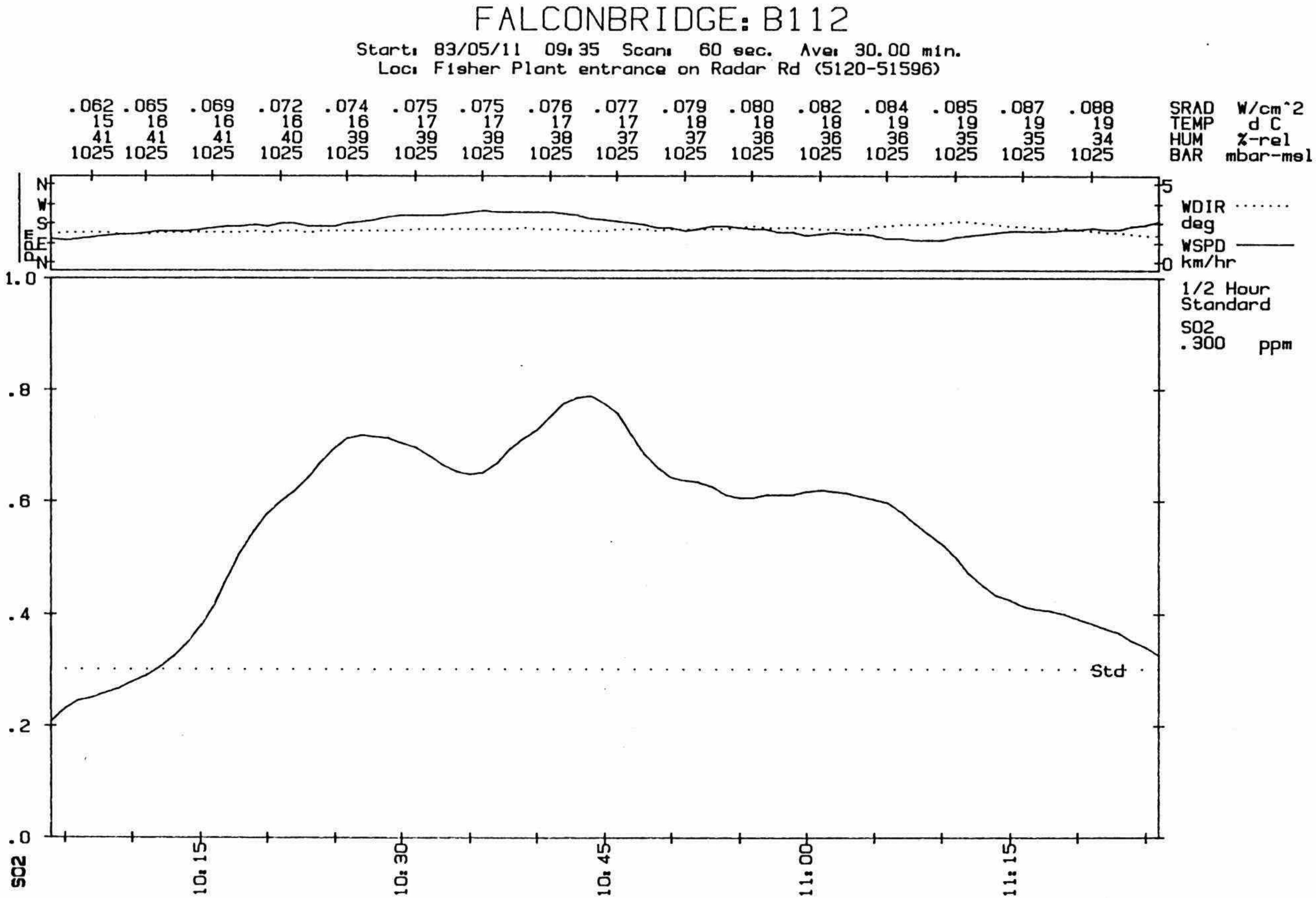
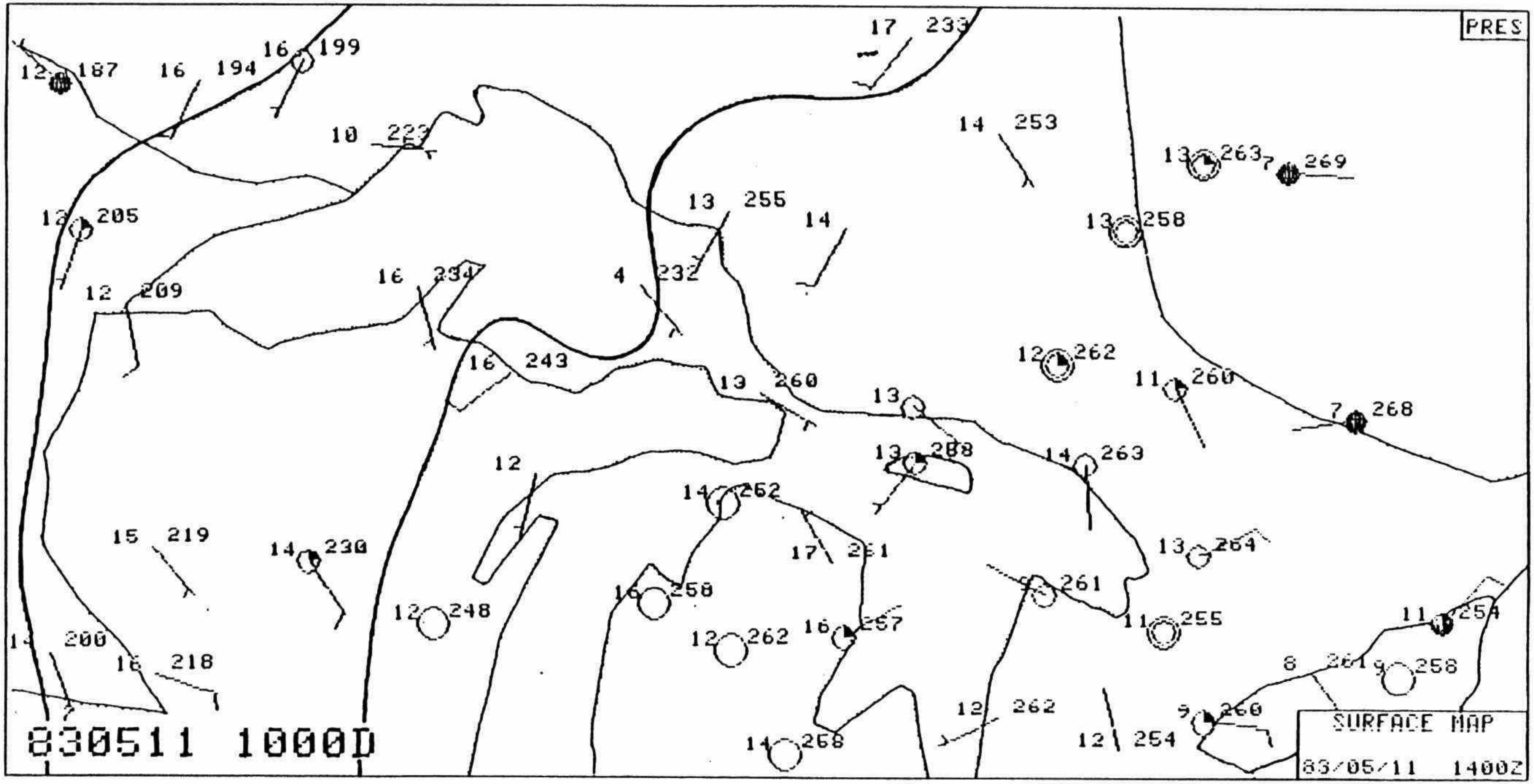

FALCONBRIDGE: B112
Start: 83/05/11 09:35 Scan: 60 sec. Ave: 30.00 min.
Loc: Fisher Plant entrance on Radar Rd (5120-51596)
.062 .065 .069 .072 .074 .075 .075 .076 .077 .079 .080 .082 .084 .085 .087 .088
15 16 16 16 16 17 17 17 17 18 18 18 19 19 19 19
41 41 41 40 39 39 38 38 37 37 36 36 36 35 35 34
1025 1025 1025 1025 1025 1025 1025 1025 1025 1025 1025 1025 1025 1025 1025 1025
SRAD W/cm^2
TEMP d C
HUM %-rel
BAR mbar-msl
N
W
S
E
N
5
0
WDIR ······ deg
WSPD —— km/hr
1/2 Hour Standard
SO2 .300 ppm
1.0
.8
.6
.4
.2
.0
Std
SO2
10:15
10:30
10:45
11:00
11:15

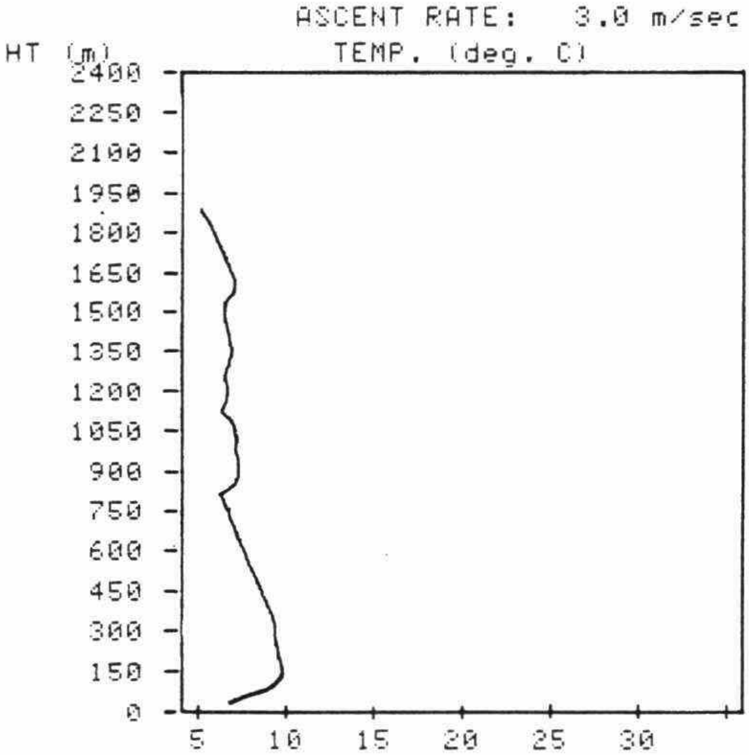
FIGURE 10



SURFACE WEATHER MAP AT 1400Z, MAY 11, 1983.

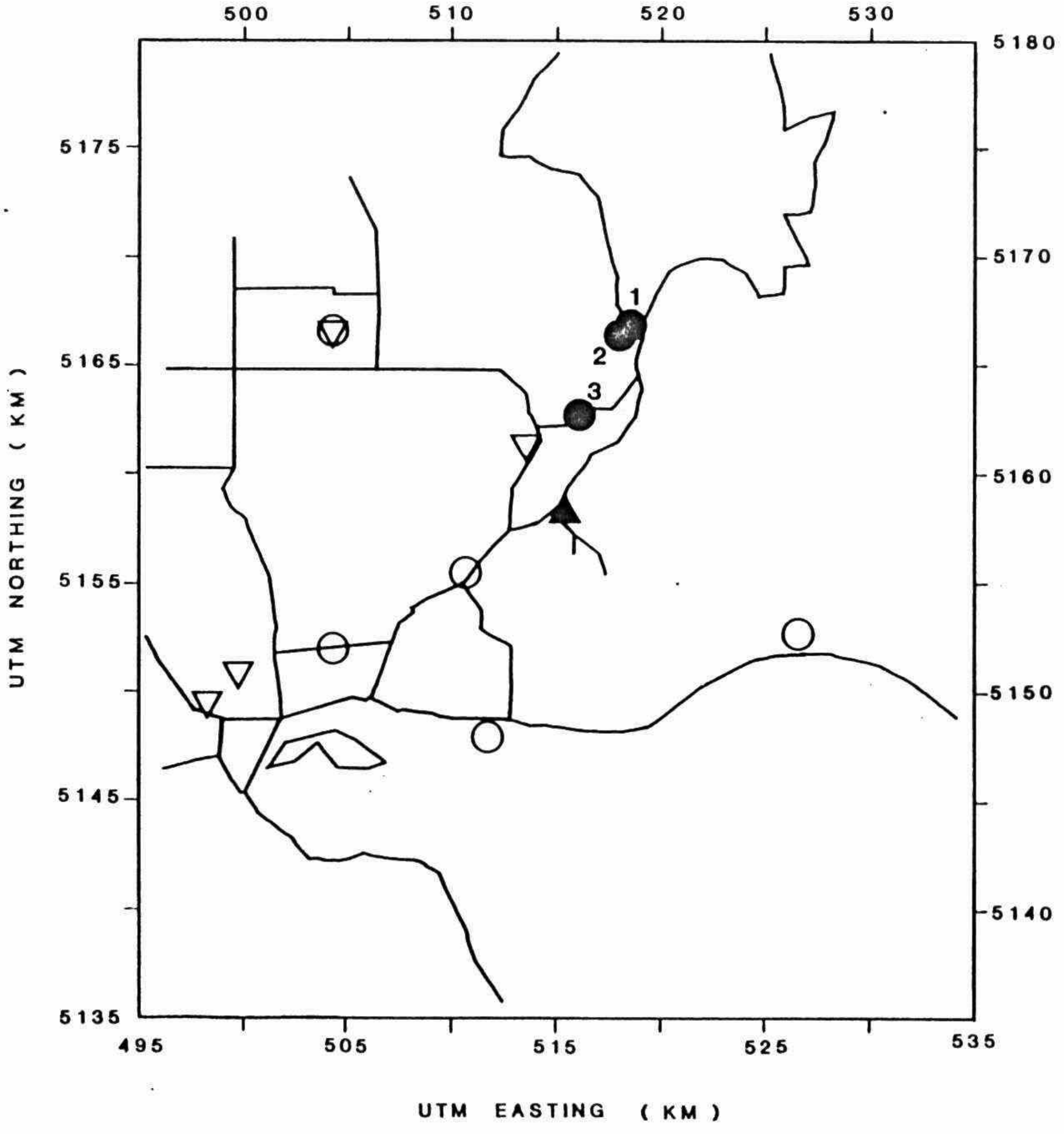
FIGURE 11

TEMPERATURE PROFILE WITH HEIGHT, MAY 11, 1983.



```
NAME: FALCONBRIDGE_UA:M112A
LOC:  GARAGE
MET:  CLEAR LIGHT WIND
ELEV:       300.0 m.
BASE:       100.0 m.                         GND TEMP:   7.4 deg.C
                                             BEARING : 224.0 deg.
```

FIGURE 12



MEASURED EXCEEDENCES

MAY 13, 1983

1/2 Hr. Standard:

Site 1	(Skead)	900-930	.34 ppm
Site 1	(Skead)	930-1000	1.10 ppm
Site 1	(Skead)	1000-1030	.72 ppm
Site 2	(MAMU 8)	1000-1030	.58 ppm
Site 1	(Skead)	1030-1100	.44 ppm
Site 3	(MAMU 1)	1120-1150	.48 ppm

1 Hr. Criterion:

Site 1	(Skead)	900-1000	.72 ppm
Site 1	(Skead)	1000-1100	.58 ppm
Site 2	(MAMU 8)	1000-1100	.32 ppm

SYMBOLS:

- ○ SO_2 monitors (fixed or mobile)
- ▲ Falconbridge
- ▽ Met. stations (including MTC garage)
- ● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion
- ▼ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 13

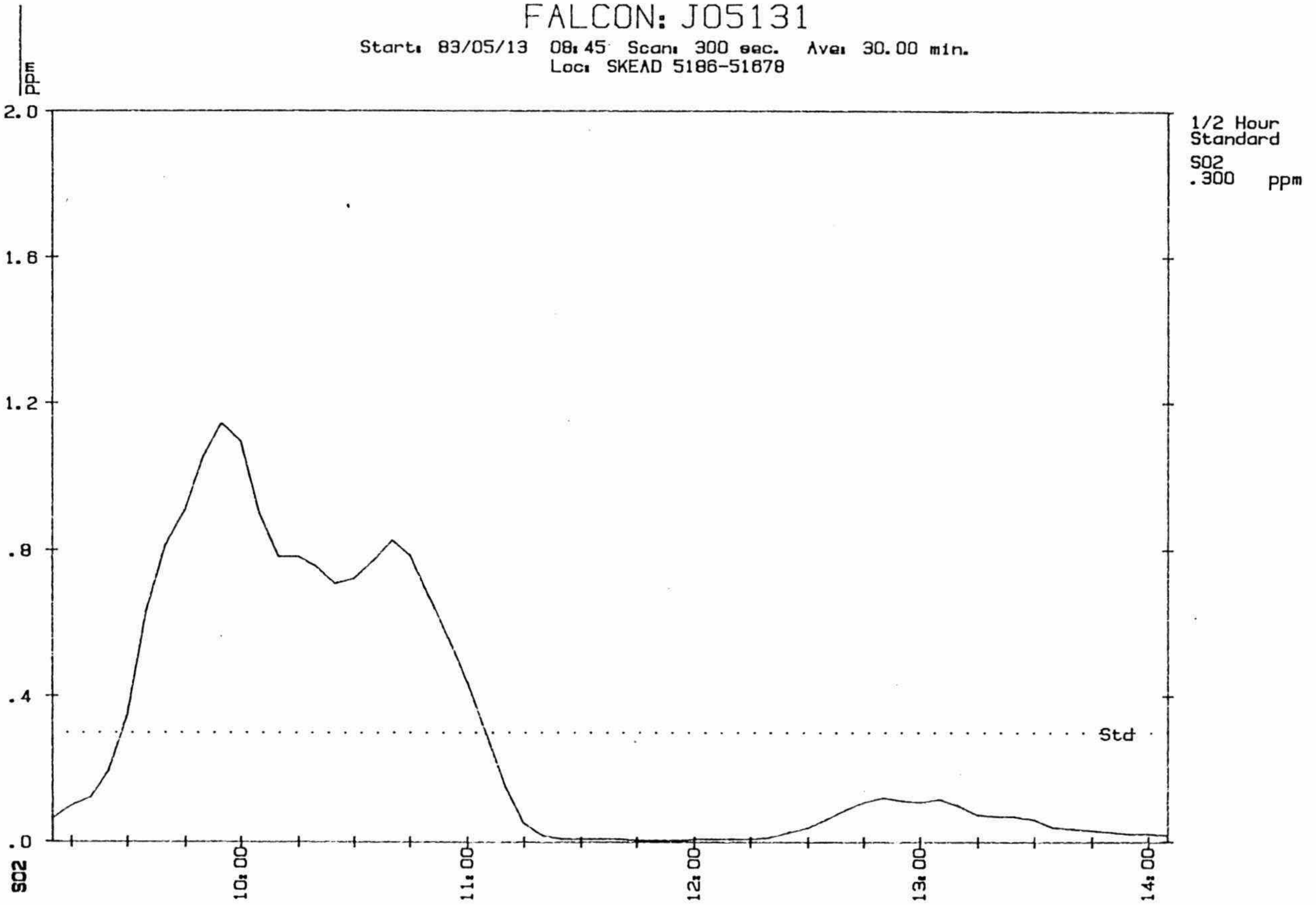

FALCON: J05131
Start: 83/05/13 08:45 Scan: 300 sec. Ave: 30.00 min.
Loc: SKEAD 5186-51678
ppm
2.0
1.6
1.2
.8
.4
.0
SO2
10:00
11:00
12:00
13:00
14:00
1/2 Hour Standard
SO2
.300 ppm
Std

FIGURE 14

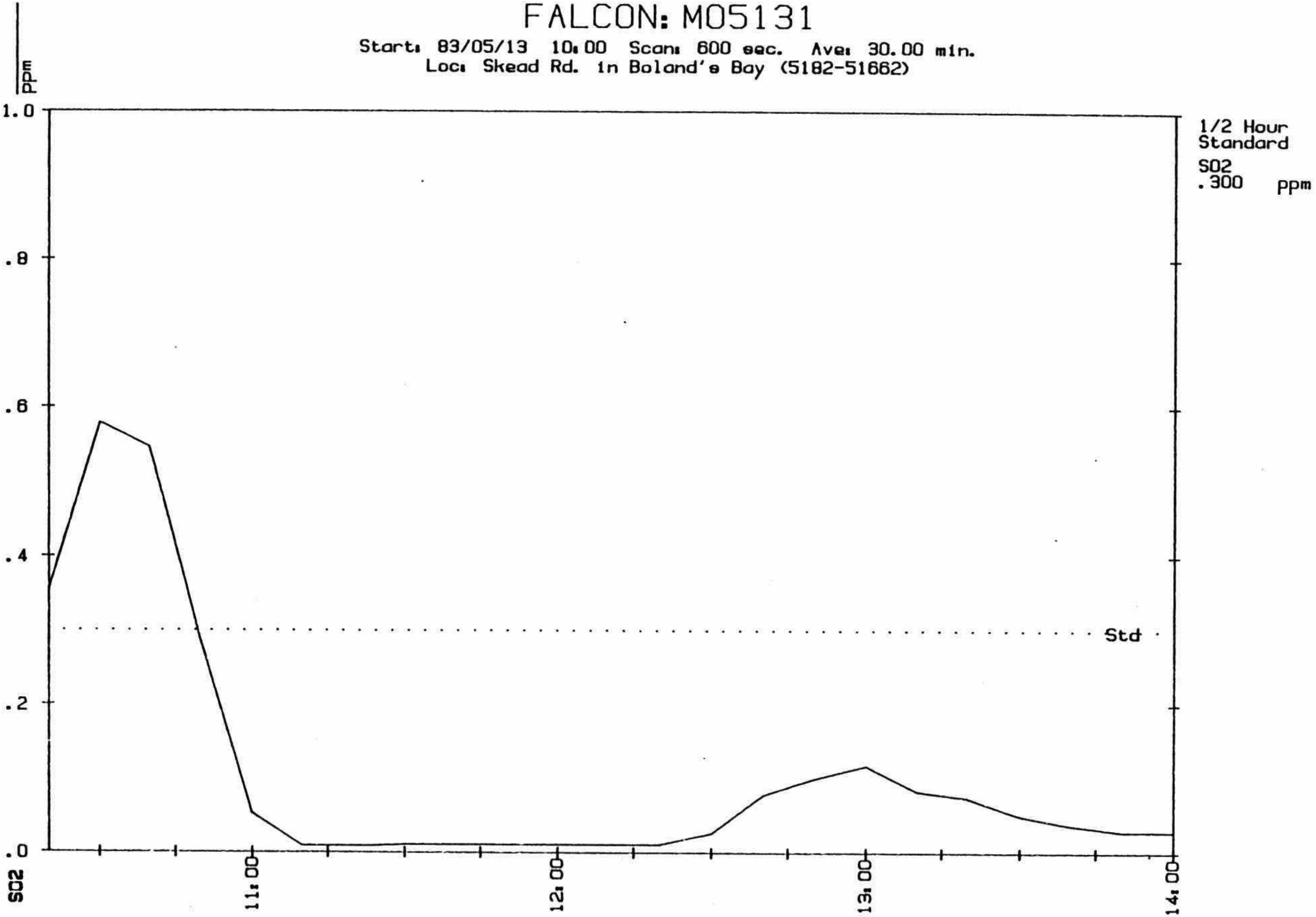

FALCON: M05131
Start: 83/05/13 10:00 Scan: 600 sec. Ave: 30.00 min.
Loc: Skead Rd. in Boland's Bay (5182-51662)
ppm
1.0
.8
.6
.4
.2
.0
SO2
11:00
12:00
13:00
14:00
1/2 Hour Standard
SO2
.300 ppm
Std

FIGURE 15

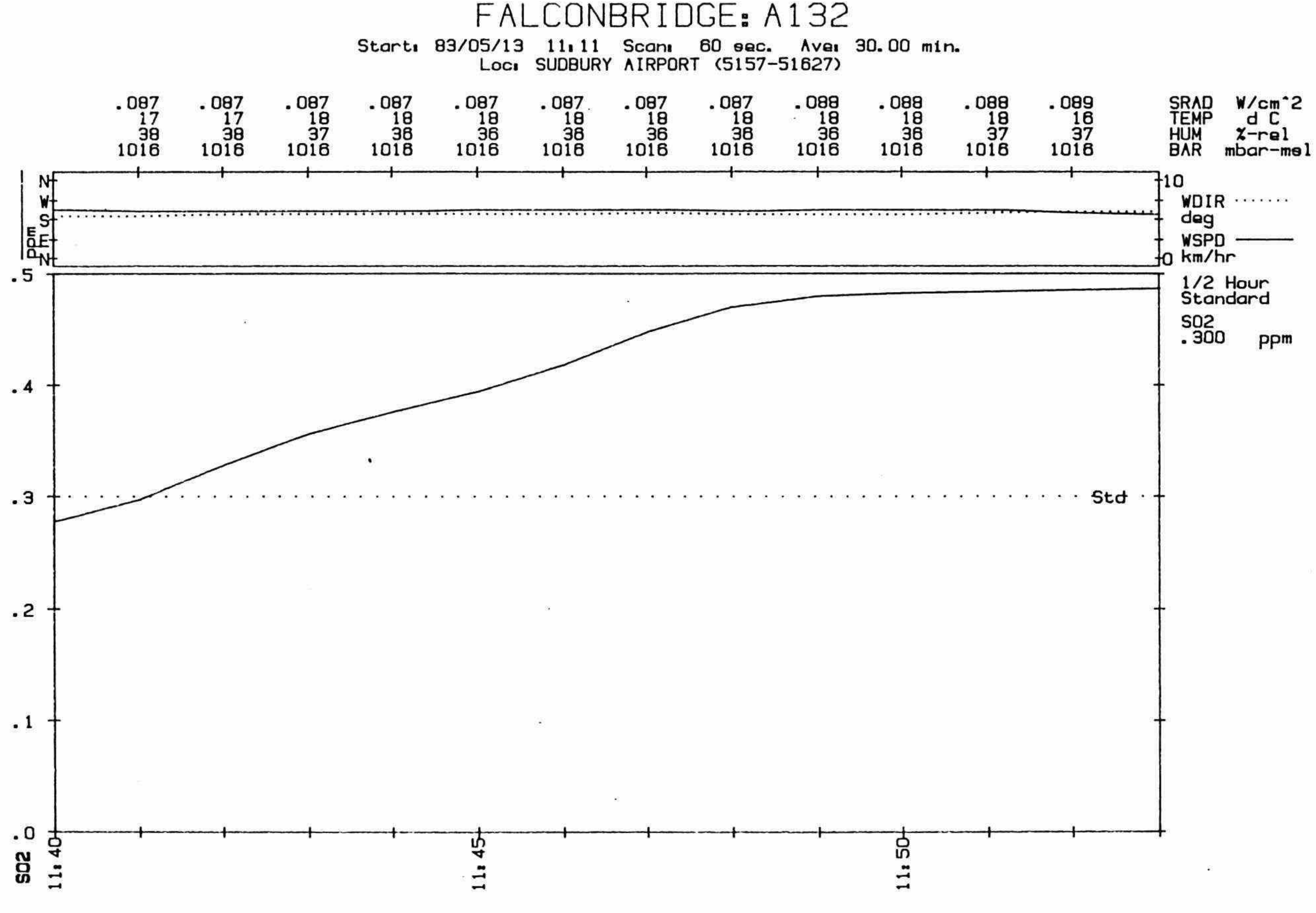
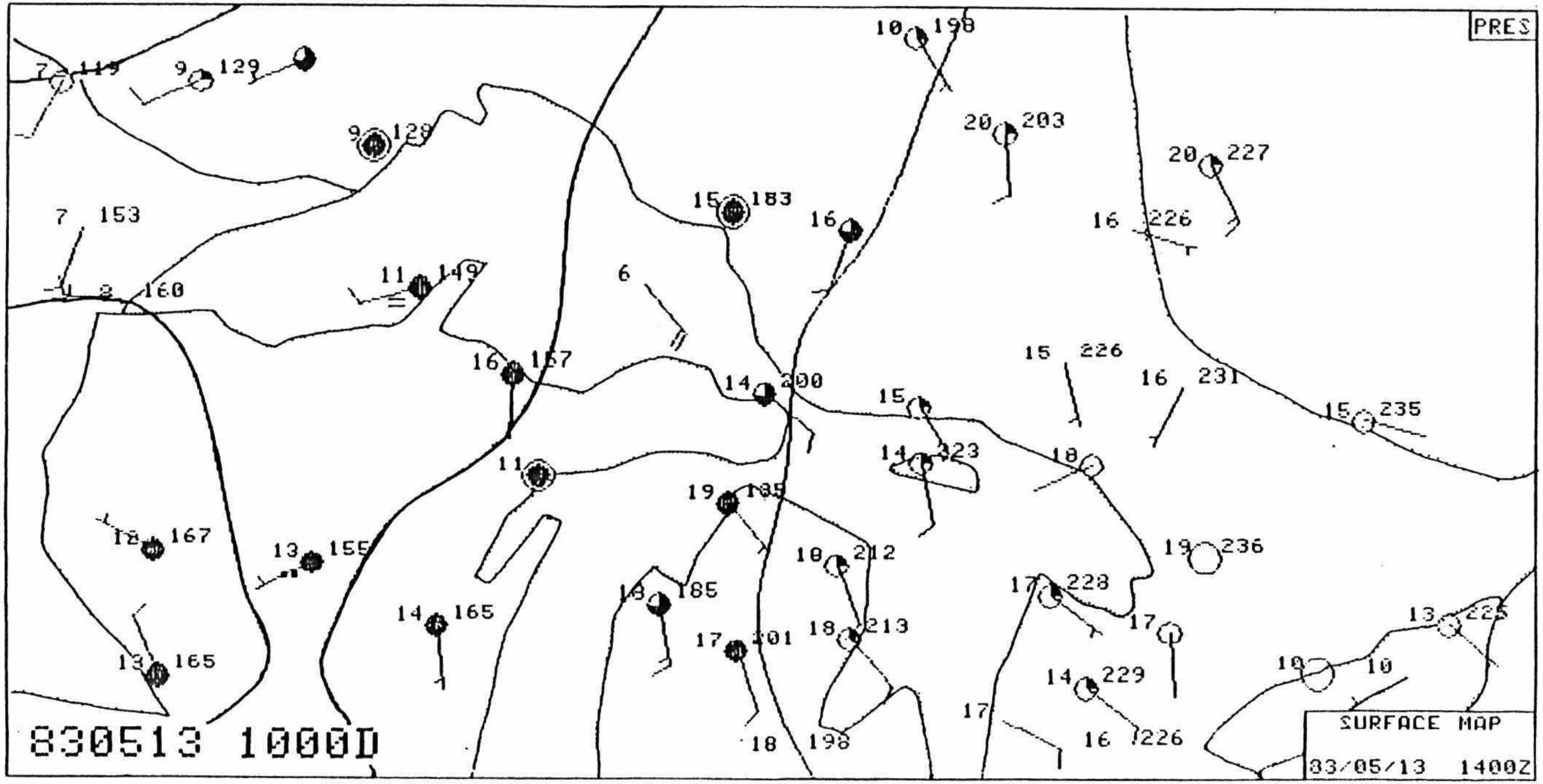

FALCONBRIDGE: A132
Start: 83/05/13 11:11 Scan: 60 sec. Ave: 30.00 min.
Loc: SUDBURY AIRPORT (5157-51627)
.087 .087 .087 .087 .087 .087 .087 .087 .088 .088 .088 .089
17 17 18 18 18 18 18 18 18 18 18 16
38 38 37 36 36 36 36 36 36 36 37 37
1016 1016 1016 1016 1016 1016 1016 1016 1016 1016 1016 1016
SRAD W/cm^2
TEMP d C
HUM %-rel
BAR mbar-msl
N
W
S
E
N
mph
10
0
WDIR
deg
WSPD
km/hr
1/2 Hour Standard
SO2
.300 ppm
.5
.4
.3
.2
.1
.0
Std
SO2
11:40
11:45
11:50

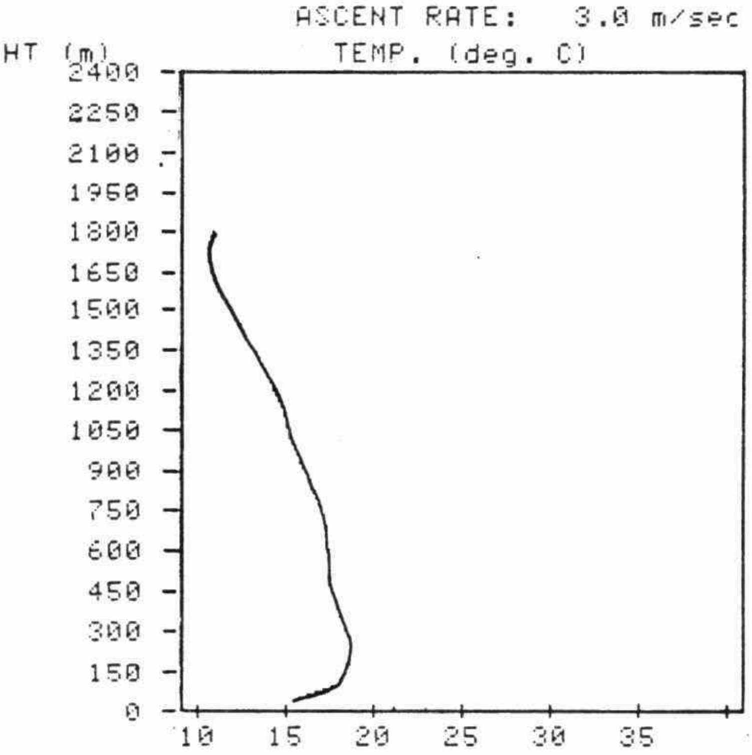
FIGURE 16



SURFACE WEATHER MAP AT 1400Z, MAY 13, 1983.

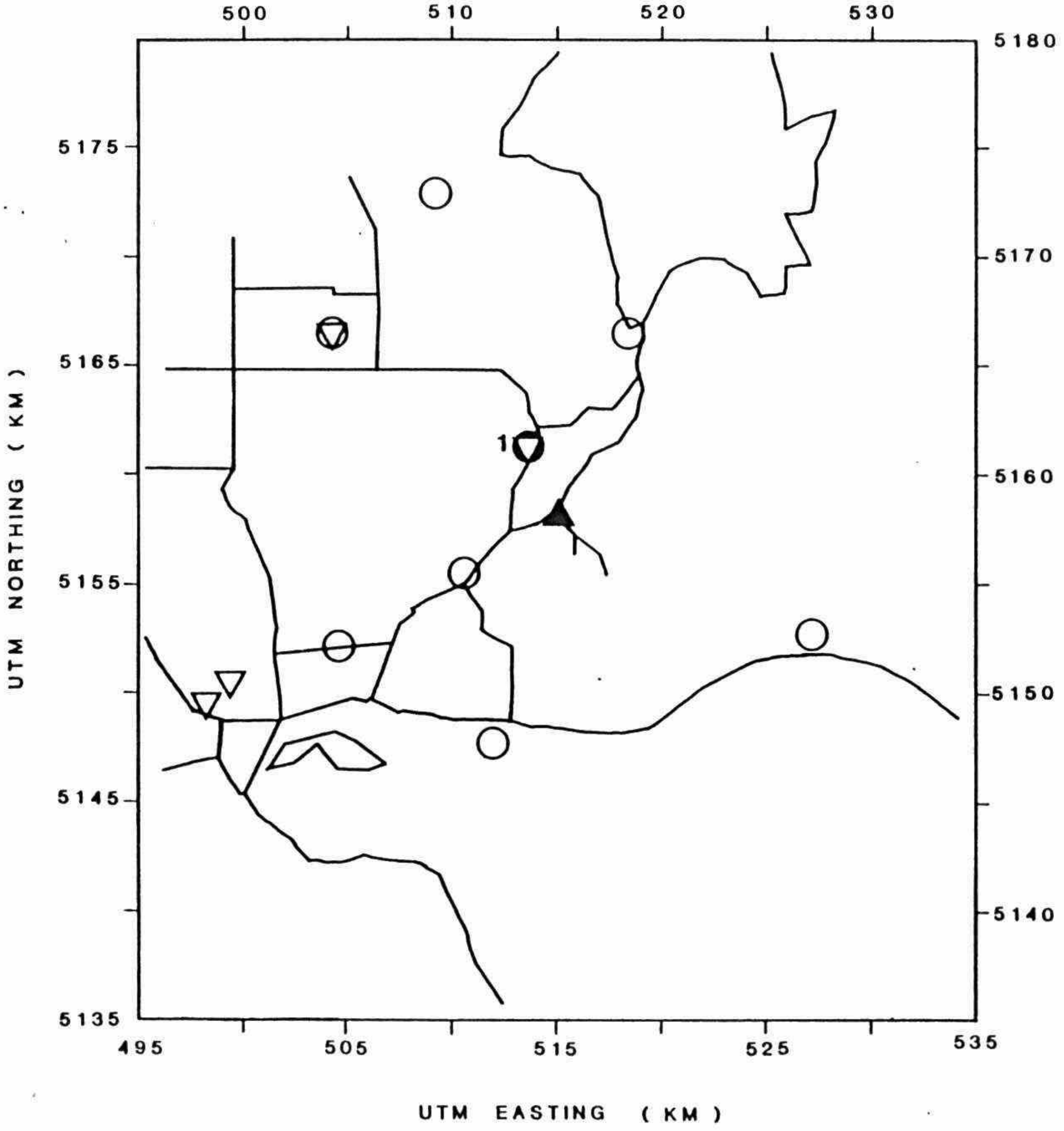
FIGURE 17

TEMPERATURE PROFILE WITH HEIGHT, MAY 13, 1983.



```
NAME: FALCONBRIDGE'_UA:M132A
LOC:  GARAGE
MET:  CLEAR CALM WARM
ELEV:        300.0 m.                        GND TEMP:  10.7 deg.C
BASE:        100.0 m.                        BEARING : 134.0 deg.
```

FIGURE 18



MEASURED EXCEEDENCES

MAY 17, 1983

1/2 Hr. Standard:

Site 1	**(MAMU 8)**	**805-835**	**.66 ppm**
Site 1	**(MAMU 1)**	**835-905**	**.97 ppm**
Site 1	**(MAMU 1)**	**905-935**	**.35 ppm**

1 Hr. Criterion:

Site 1	**(MAMU 8)**	**750-850**	**.58 ppm**

SYMBOLS:

○	SO_2 monitors (fixed or mobile)
▲	Falconbridge
▽	Met. stations (including MTC garage)
●	Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion
▼	Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 19

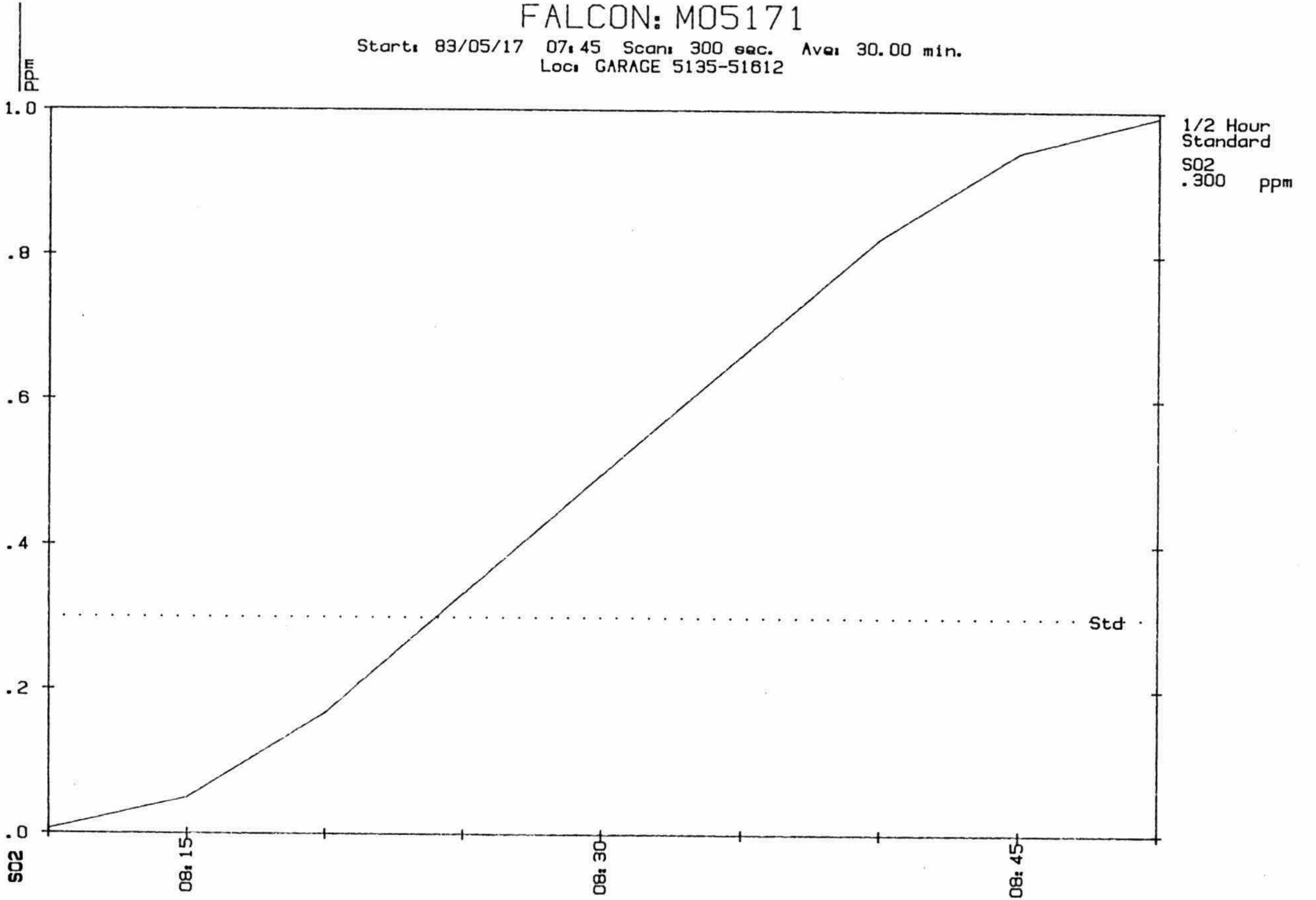

FALCON: M05171
Start: 83/05/17 07:45 Scan: 300 sec. Ave: 30.00 min.
Loc: GARAGE 5135-51812
ppm
1.0
.8
.6
.4
.2
.0
SO2
08:15
08:30
08:45
1/2 Hour Standard
SO2
.300 ppm
Std

FIGURE 20

FALCONBRIDGE: A173

Start: 83/05/17 08:33 Scan: 60 sec. Ave: 30.00 min.
Loc: MTC GARAGE AT BAILEY CORNERS (5136-51612)

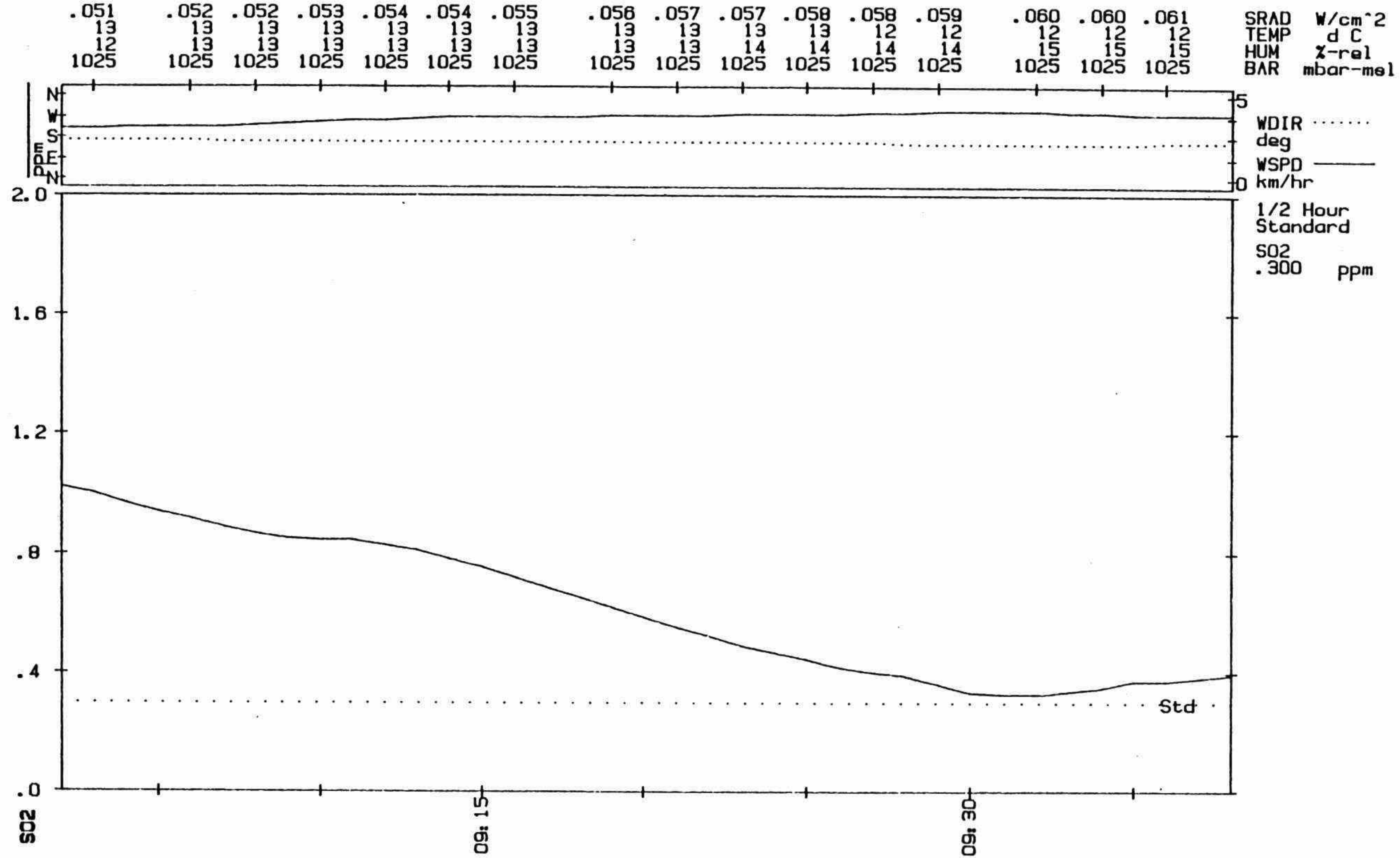
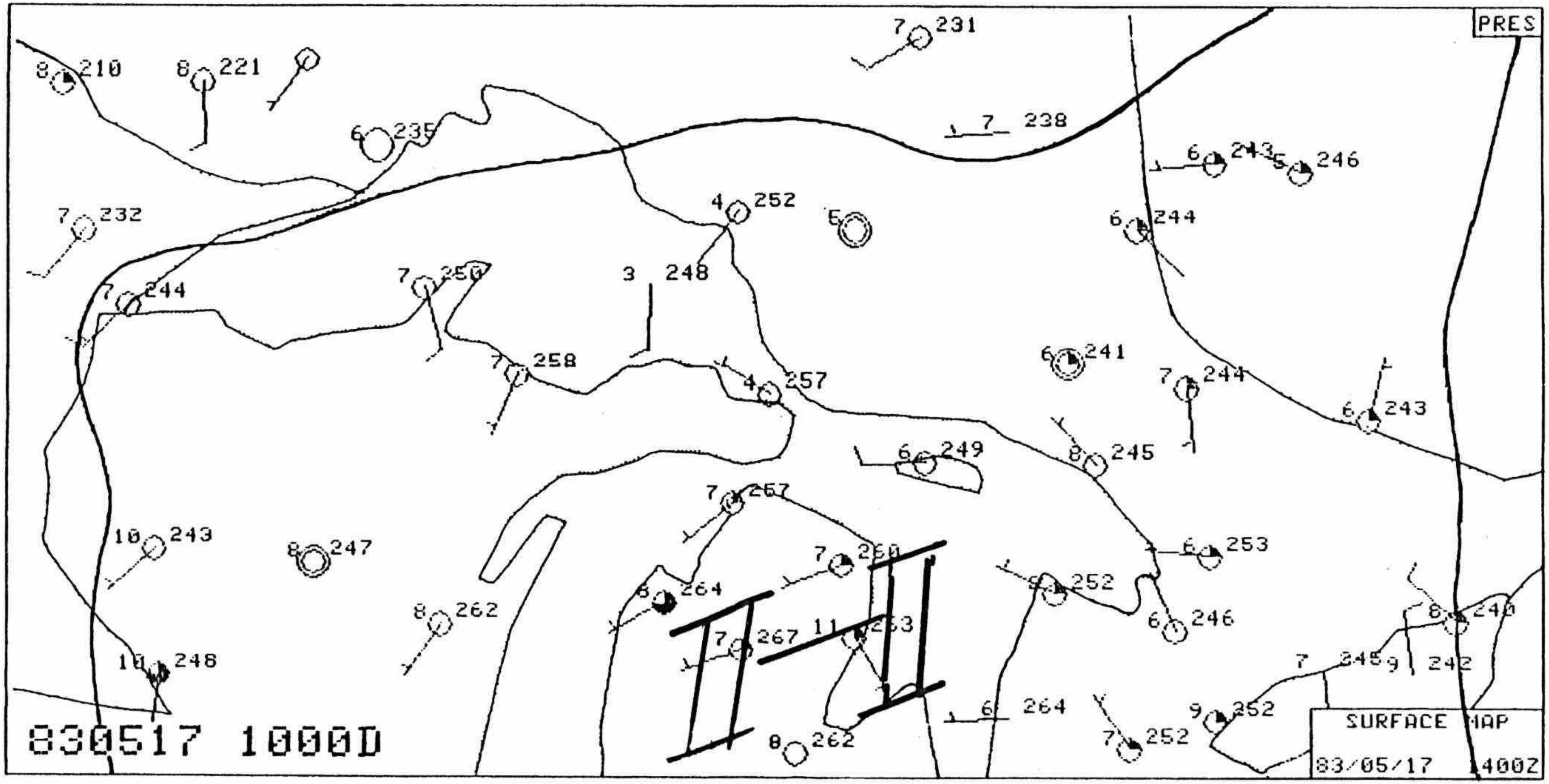


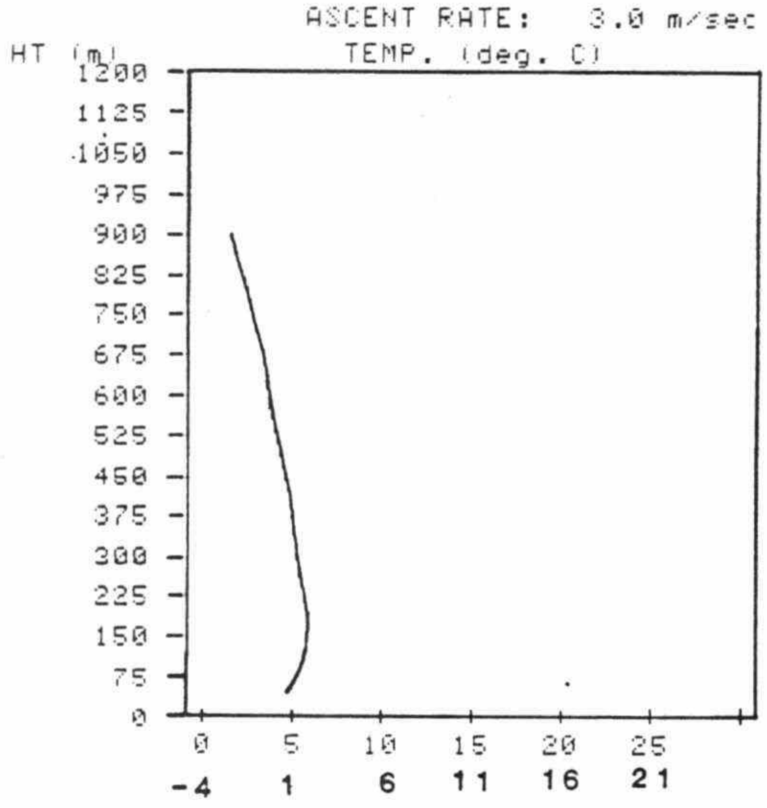
FIGURE 21



SURFACE WEATHER MAP AT 1400Z, MAY 17, 1983.

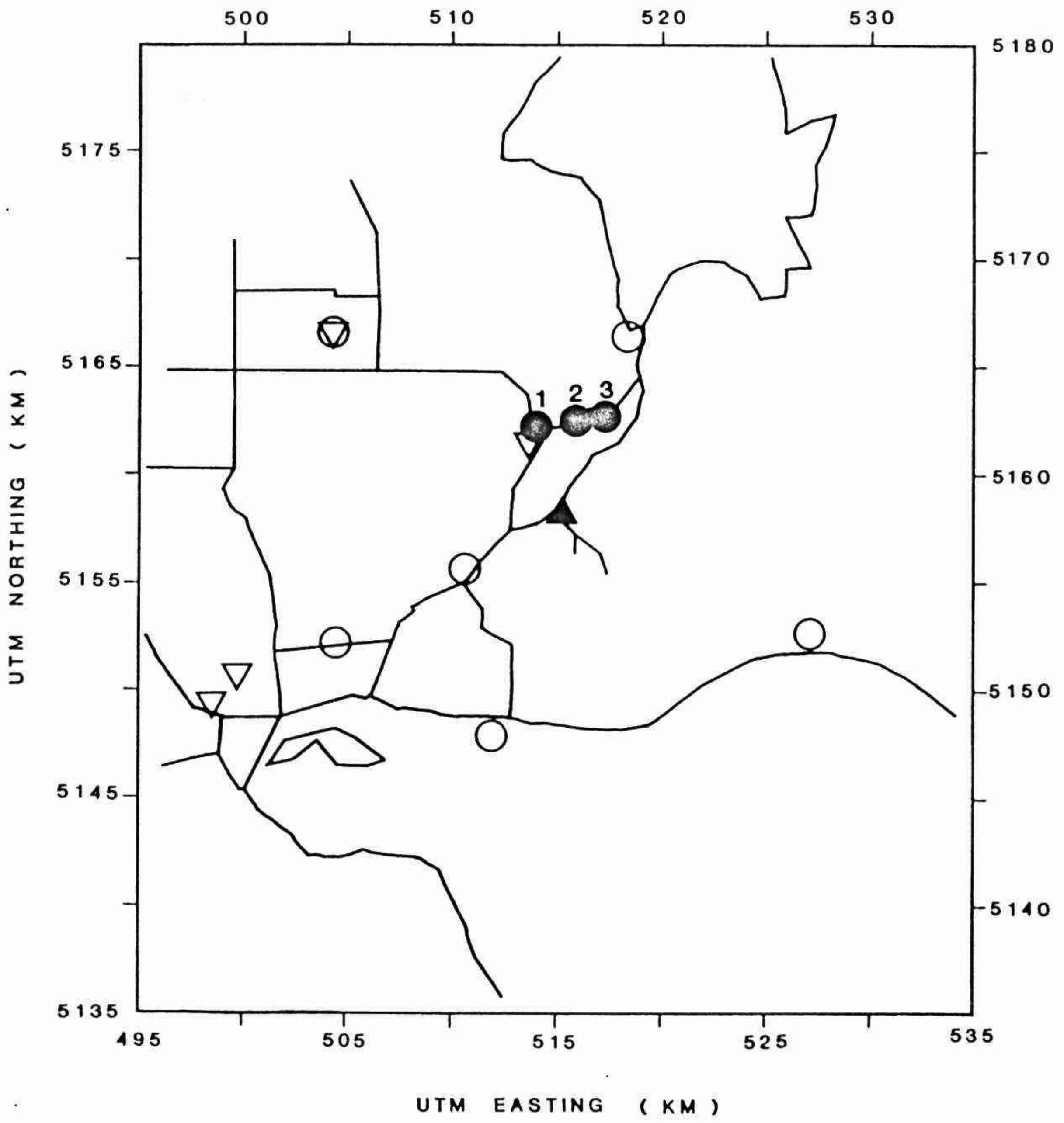
FIGURE 22

TEMPERATURE PROFILE WITH HEIGHT, MAY 17, 1983.



```
NAME: FALCONBRIDGE_UH:M171A
LOC:  GARAGE FRANK'S NEW PROG
MET:  CLEAR LIGHT SOUTHERLY WINDS
ELEV:         300.0 m.                GND TEMP:    5.0 deg.C ( 1° C )
BASE:         100.0 m.                BEARING : 134.0 deg.
```

FIGURE 23



MEASURED EXCEEDENCES

MAY 31, 1983

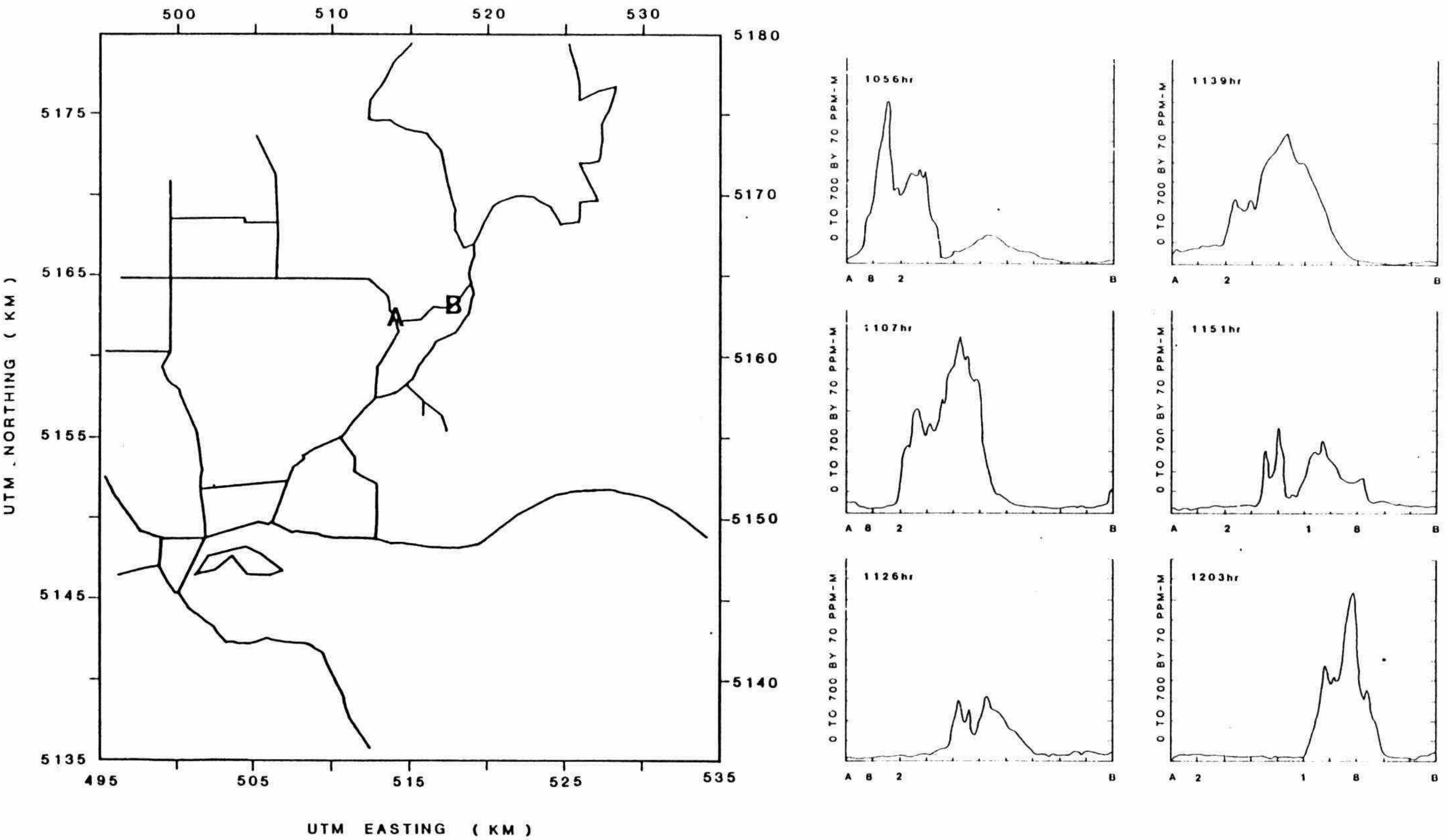
1/2 Hr. Standard:
Site 1 (MAMU 8) 1030-1100 .37 ppm
Site 2 (MAMU 1) 1300-1330 .58 ppm
Site 3 (MAMU 8) 1315-1345 .48 ppm

1 Hr. Criterion:
Site 1 (MAMU 8) 1025-1125 .27 ppm
Site 2 (MAMU 1) 1230-1330 .32 ppm

SYMBOLS:

○ SO_2 monitors (fixed or mobile)
▲ Falconbridge
▽ Met. stations (including MTC garage)
● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion
▼ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 24



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - May 31

FIGURE 25A

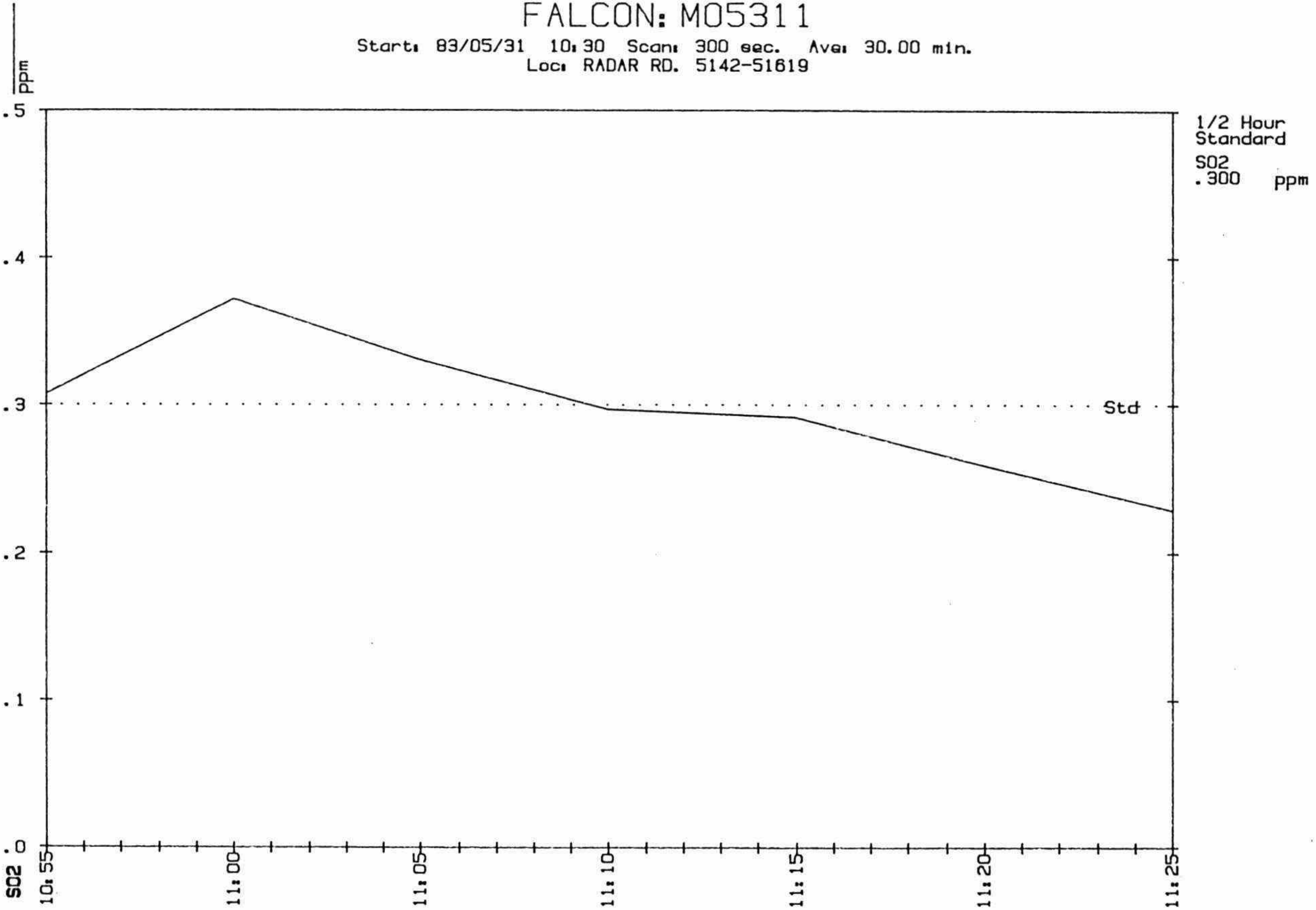

FALCON: M05311
Start: 83/05/31 10:30 Scan: 300 sec. Ave: 30.00 min.
Loc: RADAR RD. 5142-51619
ppm
.5
.4
.3
.2
.1
.0
SO2
10:55
11:00
11:05
11:10
11:15
11:20
11:25
Std
1/2 Hour Standard
SO2
.300 ppm

FIGURE 25B

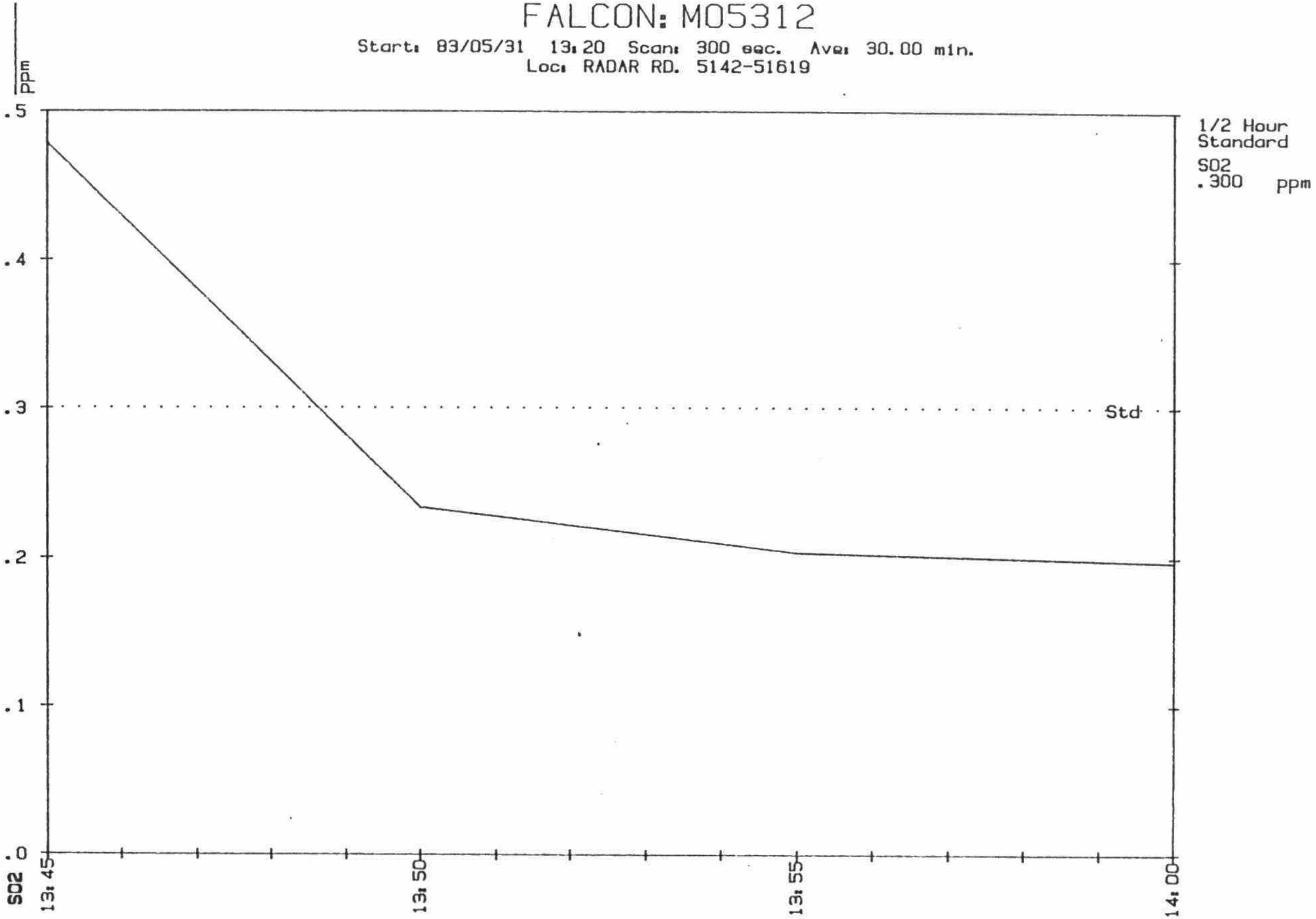

FALCON: M05312
Start: 83/05/31 13:20 Scan: 300 sec. Ave: 30.00 min.
Loc: RADAR RD. 5142-51619
ppm
.5
.4
.3
.2
.1
.0
1/2 Hour
Standard
SO2
.300 ppm
Std
SO2
13:45
13:50
13:55
14:00

FIGURE 26

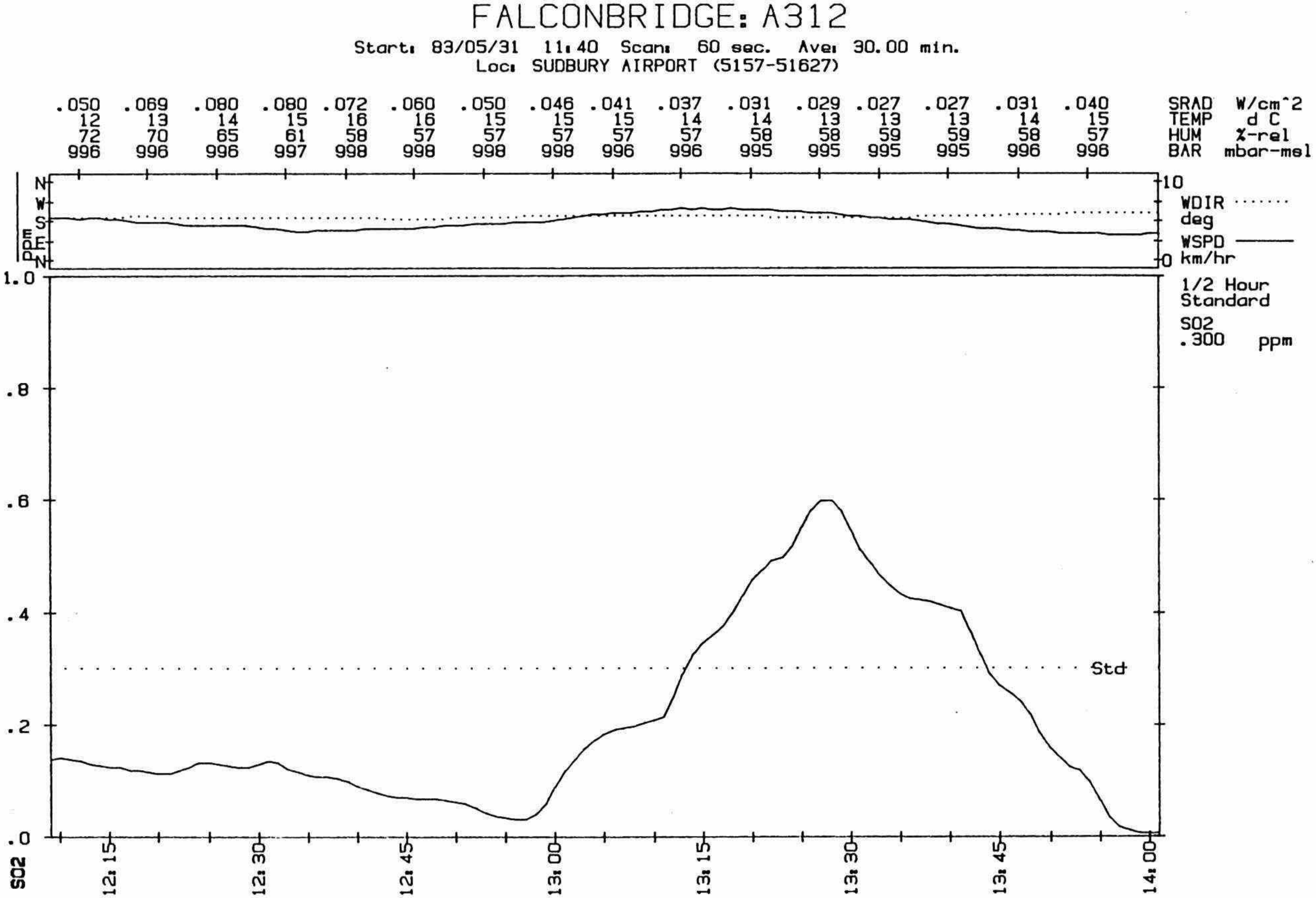
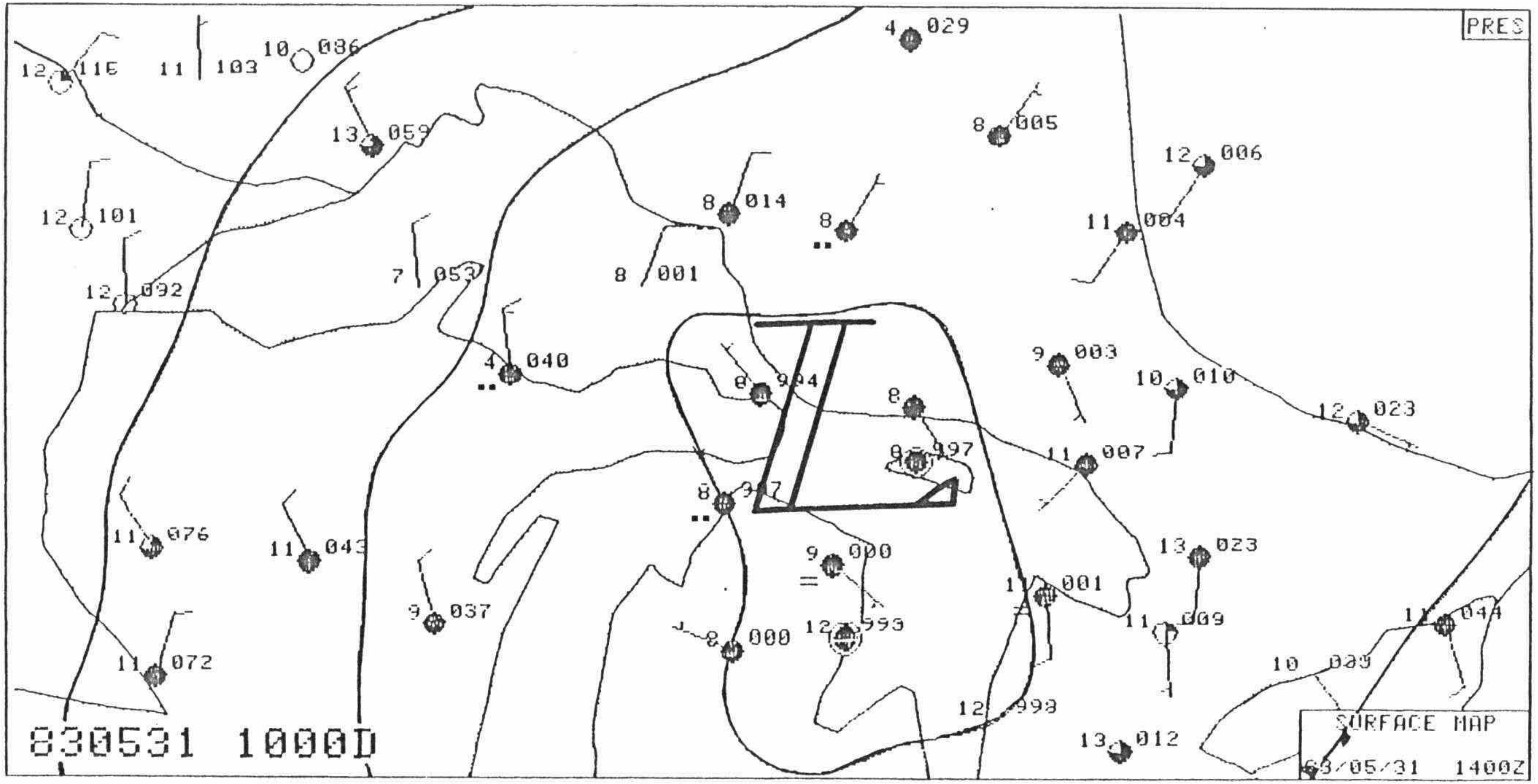

FALCONBRIDGE: A312
Start: 83/05/31 11:40 Scan: 60 sec. Ave: 30.00 min.
Loc: SUDBURY AIRPORT (5157-51627)
.050 .069 .080 .080 .072 .060 .050 .046 .041 .037 .031 .029 .027 .027 .031 .040 SRAD W/cm^2
12 13 14 15 16 16 15 15 15 14 14 13 13 13 14 15 TEMP d C
72 70 65 61 58 57 57 57 57 57 58 58 59 59 58 57 HUM %-rel
996 996 996 997 998 998 998 998 996 996 995 995 995 995 996 996 BAR mbar-msl
N
W
S
E
N
ppm
10
WDIR
deg
WSPD
0
km/hr
1/2 Hour Standard
SO2
.300 ppm
1.0
.8
.6
.4
.2
.0
Std
SO2
12:15
12:30
12:45
13:00
13:15
13:30
13:45
14:00

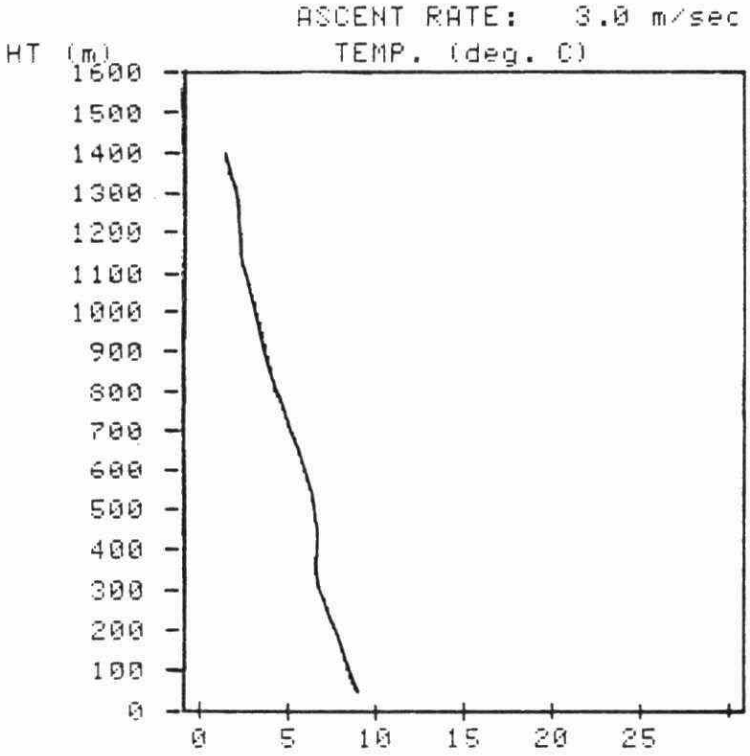
FIGURE 27



SURFACE WEATHER MAP AT 1400Z, MAY 31, 1983.

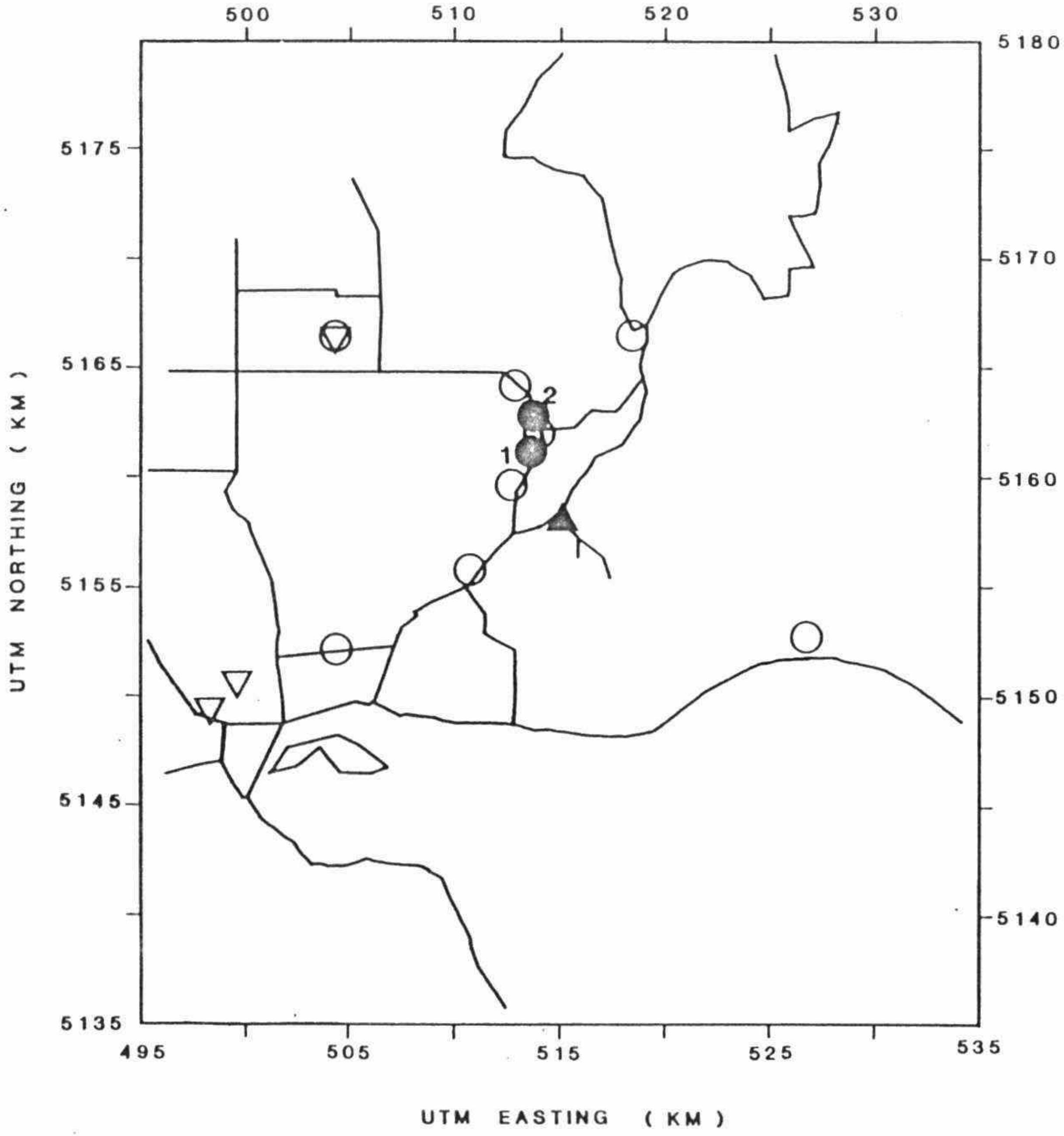
FIGURE 28

TEMPERATURE PROFILE WITH HEIGHT, MAY 31, 1983.



```
NAME: FALCONBRIDGE_UA:M311A
LOC:  GARAGE
MET:  OVERCAST S WINDS
ELEV:        300.0 m.
BASE:         90.0 m.                          GND TEMP:   9.3 deg.C
                                               BEARING : 134.0 deg.
```

FIGURE 29



MEASURED EXCEEDENCES

JUNE 9, 1983

1/2 Hr. Standard:

Site 1	(MAMU 1)	1000-1030	.36 ppm
Site 1	(MAMU 1)	1100-1130	.32 ppm
Site 1	(MAMU 1)	1130-1200	.41 ppm
Site 1	(MAMU 1)	1230-1300	.49 ppm
Site 2	(MAMU 2)	1500-1530	.43 ppm

1 Hr. Criterion:

Site 1	(MAMU 1)	0930-1030	.25 ppm
Site 1	(MAMU 1)	1100-1200	.36 ppm
Site 1	(MAMU 1)	1200-1300	.33 ppm
Site 2	(MAMU 2)	1500-1600	.30 ppm

SYMBOLS:

○ SO_2 monitors (fixed or mobile)

▲ Falconbridge

▽ Met. stations (including MTC garage)

● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion

⊽ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 30

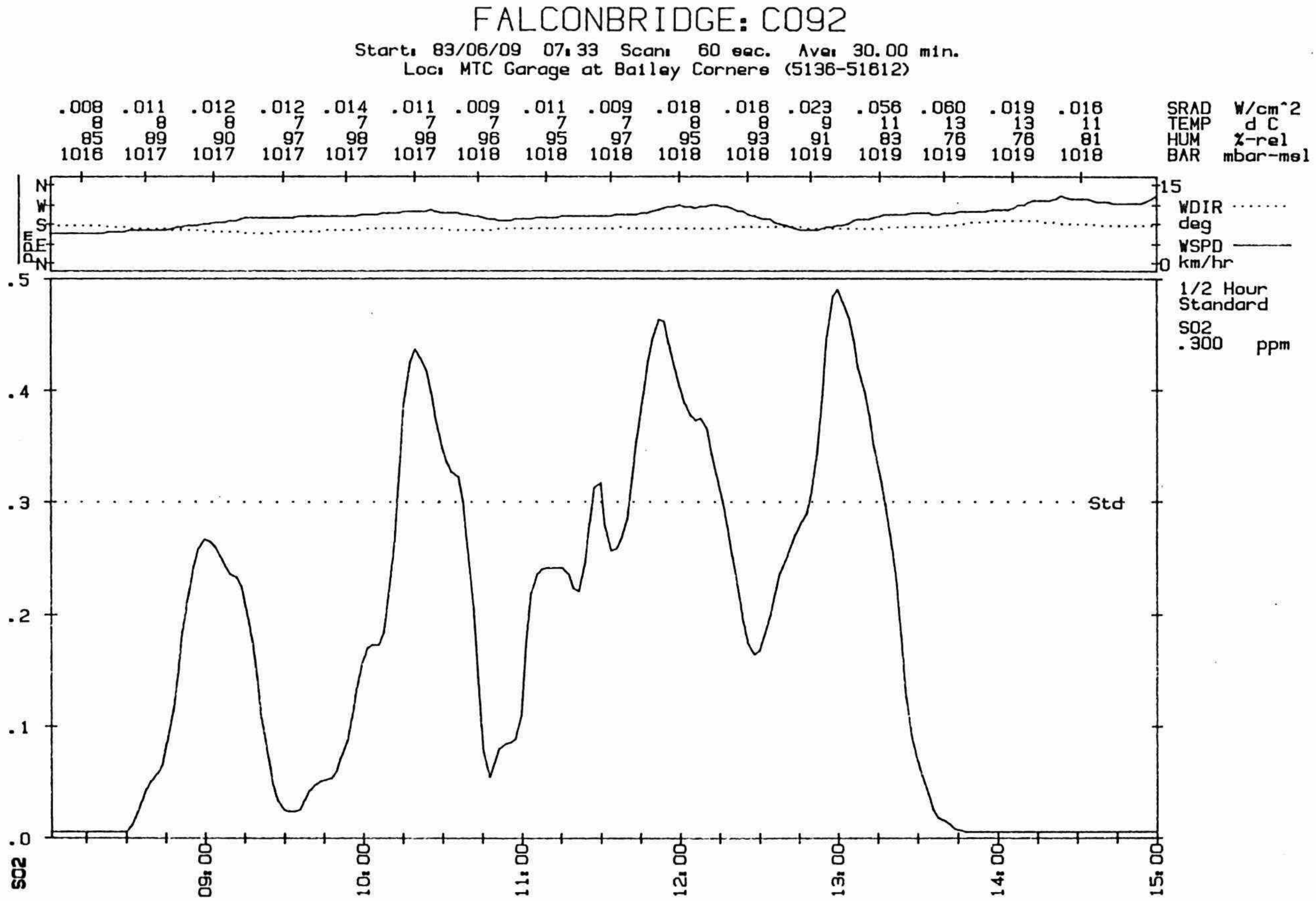
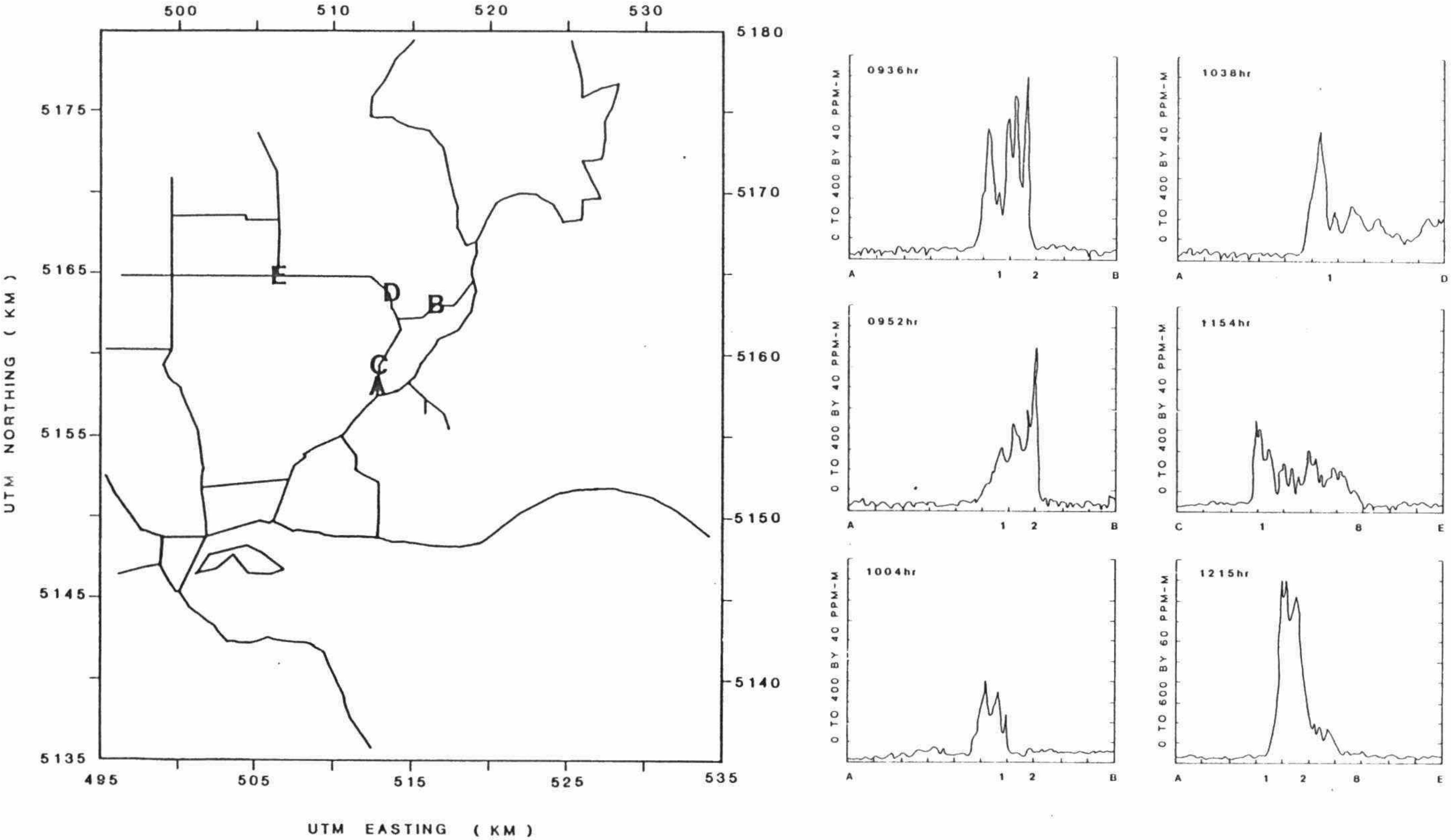
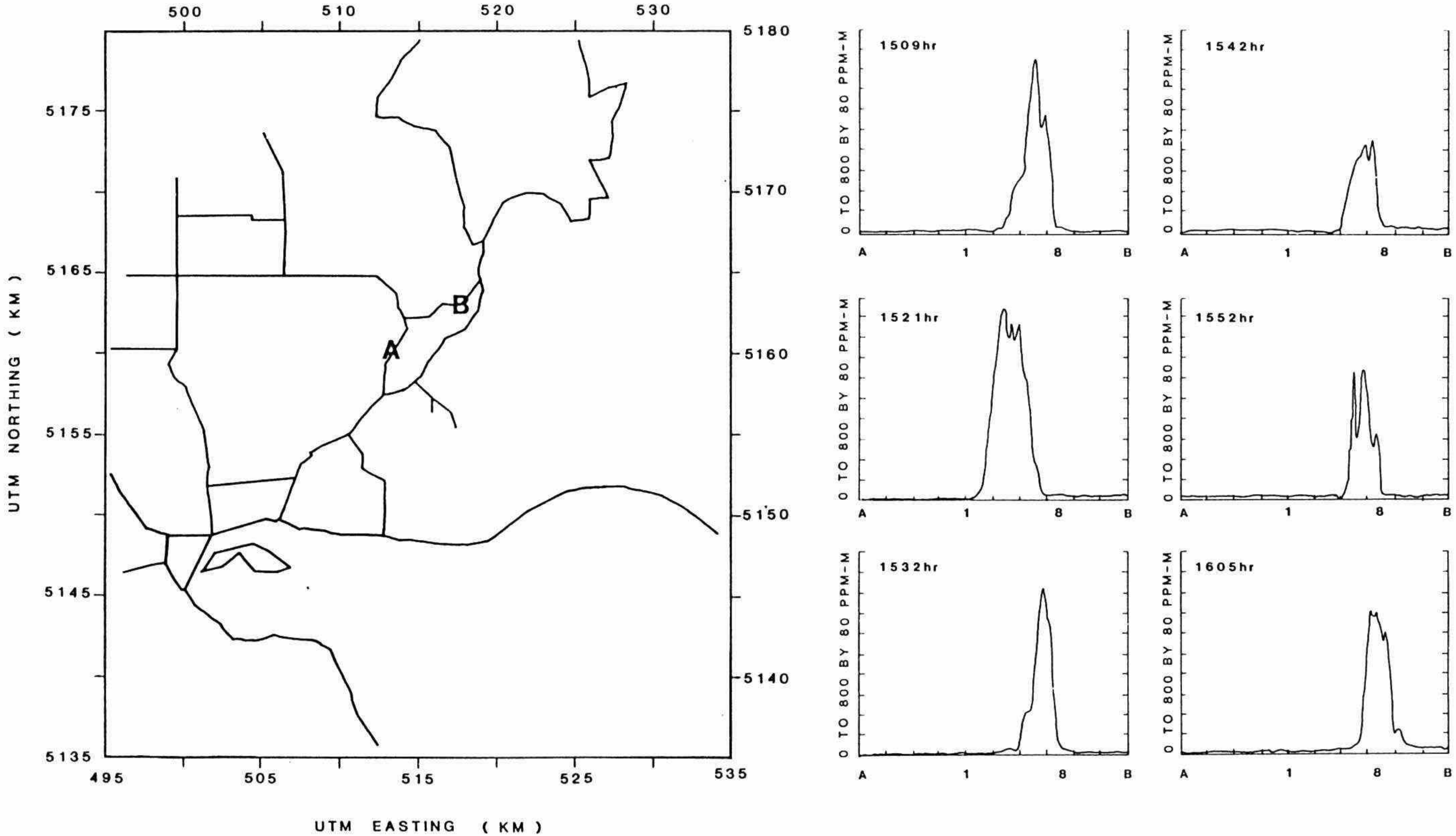

FALCONBRIDGE: C092
Start: 83/06/09 07:33 Scan: 60 sec. Ave: 30.00 min.
Loc: MTC Garage at Bailey Corners (5136-51612)
.008 .011 .012 .012 .014 .011 .009 .011 .009 .018 .018 .023 .056 .060 .019 .018 SRAD W/cm^2
8 8 8 7 7 7 7 7 7 8 8 9 11 13 13 11 TEMP d C
85 89 90 97 98 98 96 95 97 95 93 91 83 76 76 81 HUM %-rel
1016 1017 1017 1017 1017 1017 1018 1018 1018 1018 1018 1019 1019 1019 1019 1018 BAR mbar-msl
N
W
S
E
N
END
15
WDIR
deg
WSPD
0 km/hr
1/2 Hour Standard
SO2
.300 ppm
Std
.5
.4
.3
.2
.1
.0
SO2
09:00
10:00
11:00
12:00
13:00
14:00
15:00

FIGURE 31



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 9

FIGURE 32



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 9

FIGURE 33

FALCONBRIDGE: D094

Start: 83/06/09 12:19 Scan: 60 sec. Ave: 30.00 min.
Loc: Radar Rd., 1 km N of Bailey Corners (5136-51624)

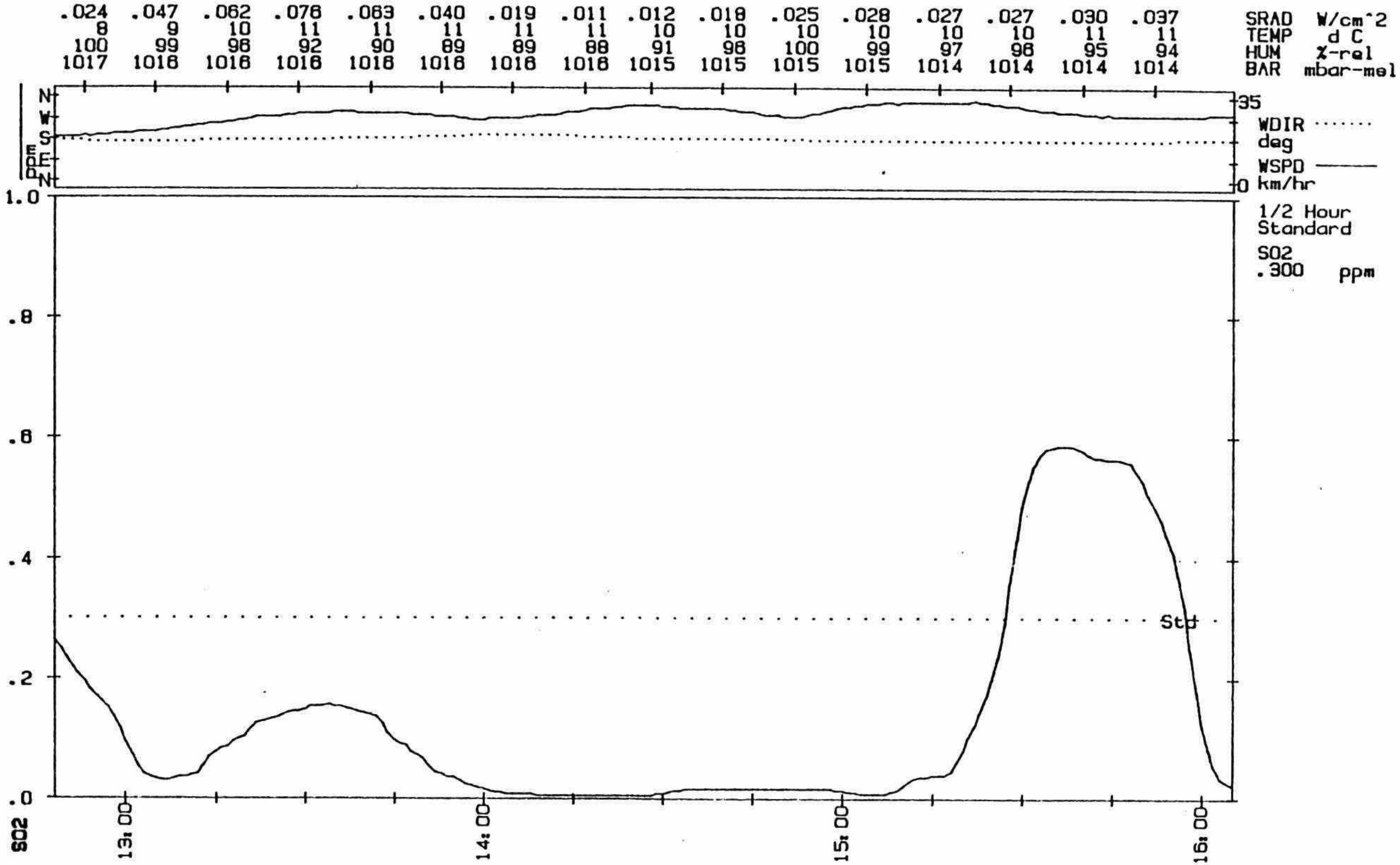
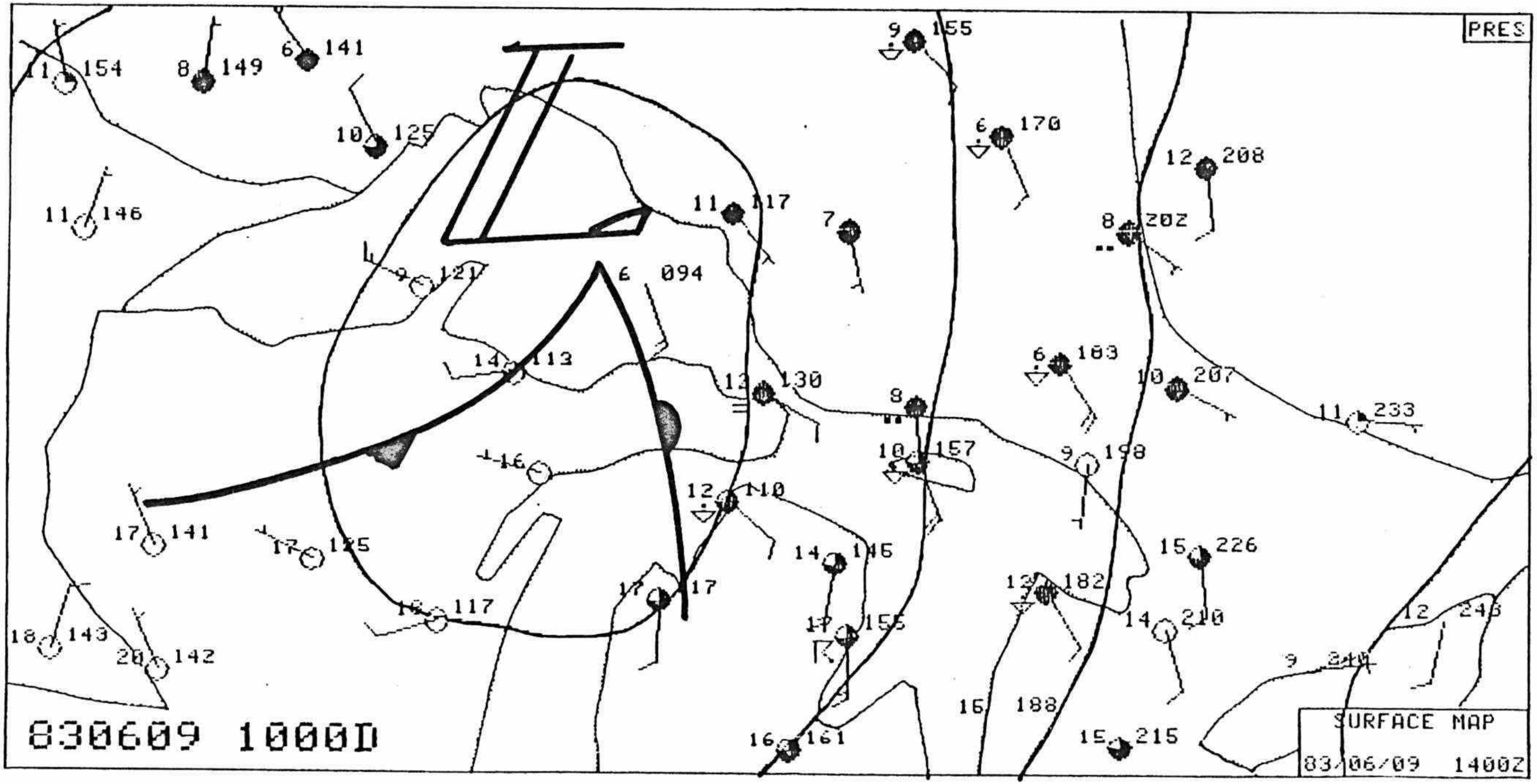


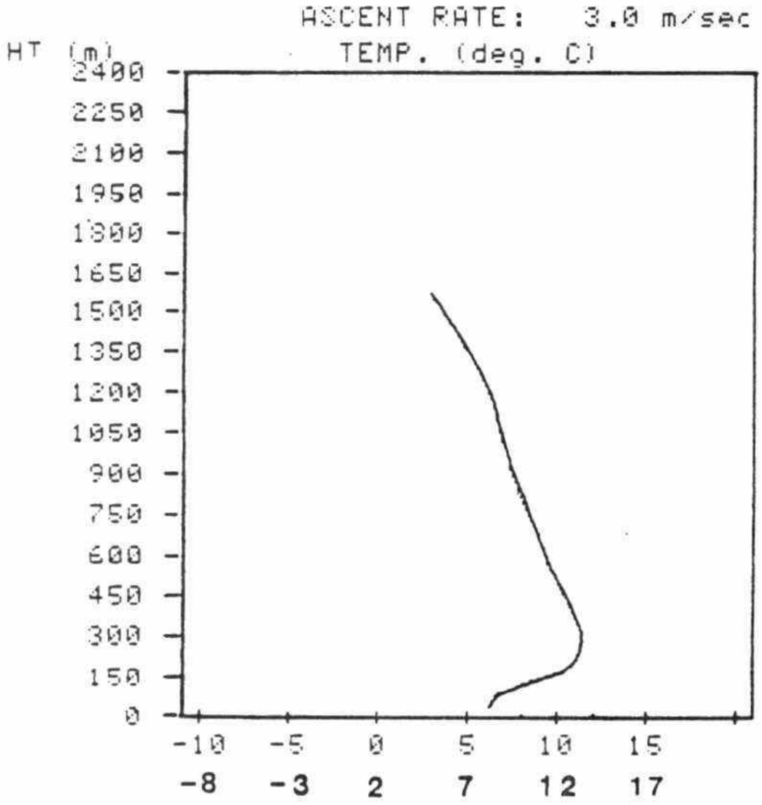
FIGURE 34



SURFACE WEATHER MAP AT 1400Z, JUNE 9, 1983.

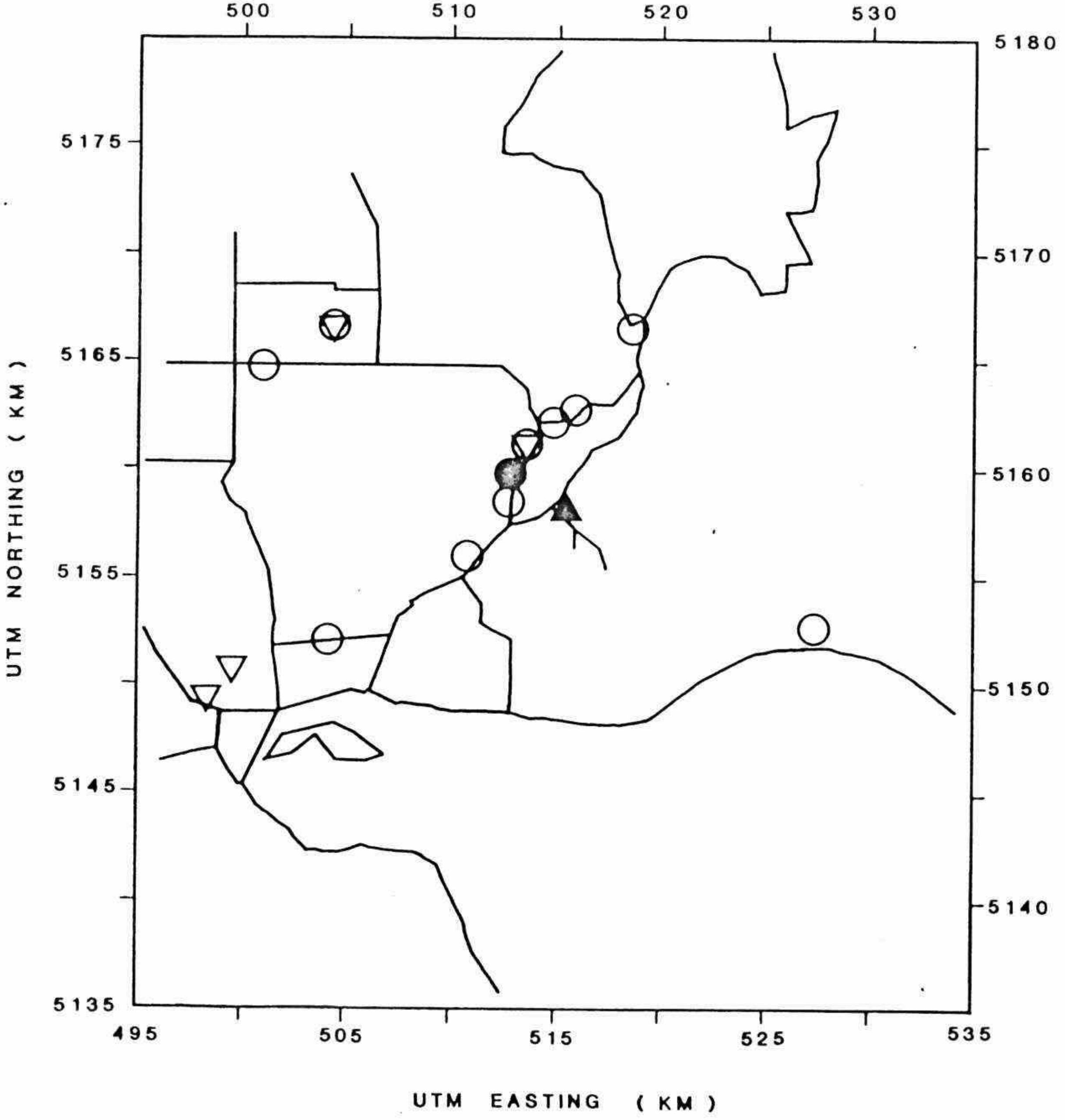
FIGURE 35

TEMPERATURE PROFILE WITH HEIGHT, JUNE 9, 1983.



```
NAME: FALCONBRIDGE_UA:C092A
LOC:  GARAGE
MET:  ALTCU OVERCAST LIGHT S WINDS
ELEV:        300.0 m.                    GND TEMP:   6.8 deg.C
BASE:        100.0 m.                    BEARING : 134.0 deg.
```

FIGURE 36



MEASURED EXCEEDENCES

JUNE 20, 1983

1/2 Hr. Standard:
Site 1 (MAMU 1) 1009-1039 .32 ppm

1 Hr. Criterion:
no exceedences measured

SYMBOLS:

○ SO_2 monitors (fixed or mobile)

▲ Falconbridge

▽ Met. stations (including MTC garage)

● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion

▼ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 37

FALCONBRIDGE: C204

Start: 83/06/20 10:08 Scan: 60 sec. Ave: 30.00 min.
Loc: Skead Rd in little Village S of Garage (5117-51592)

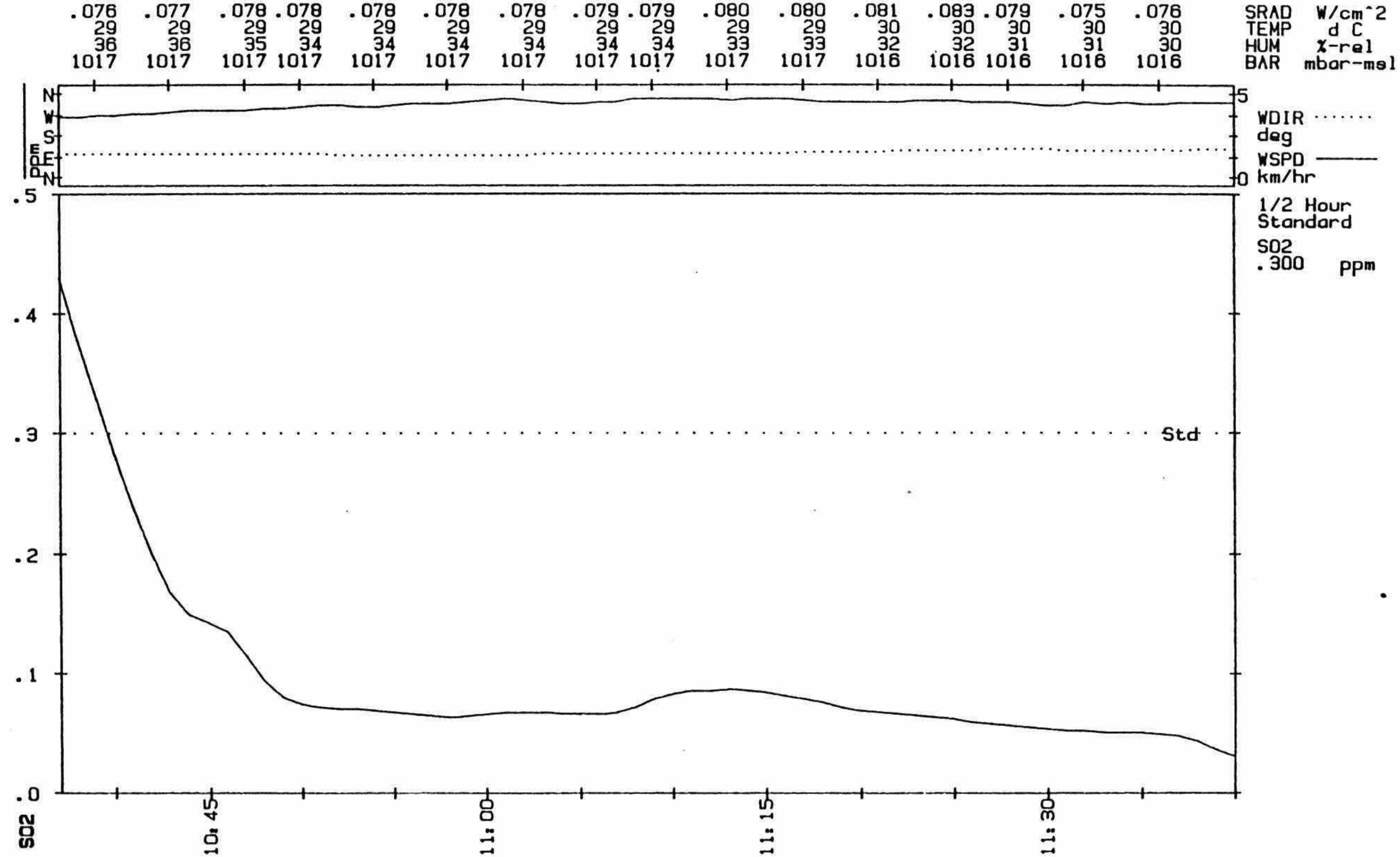
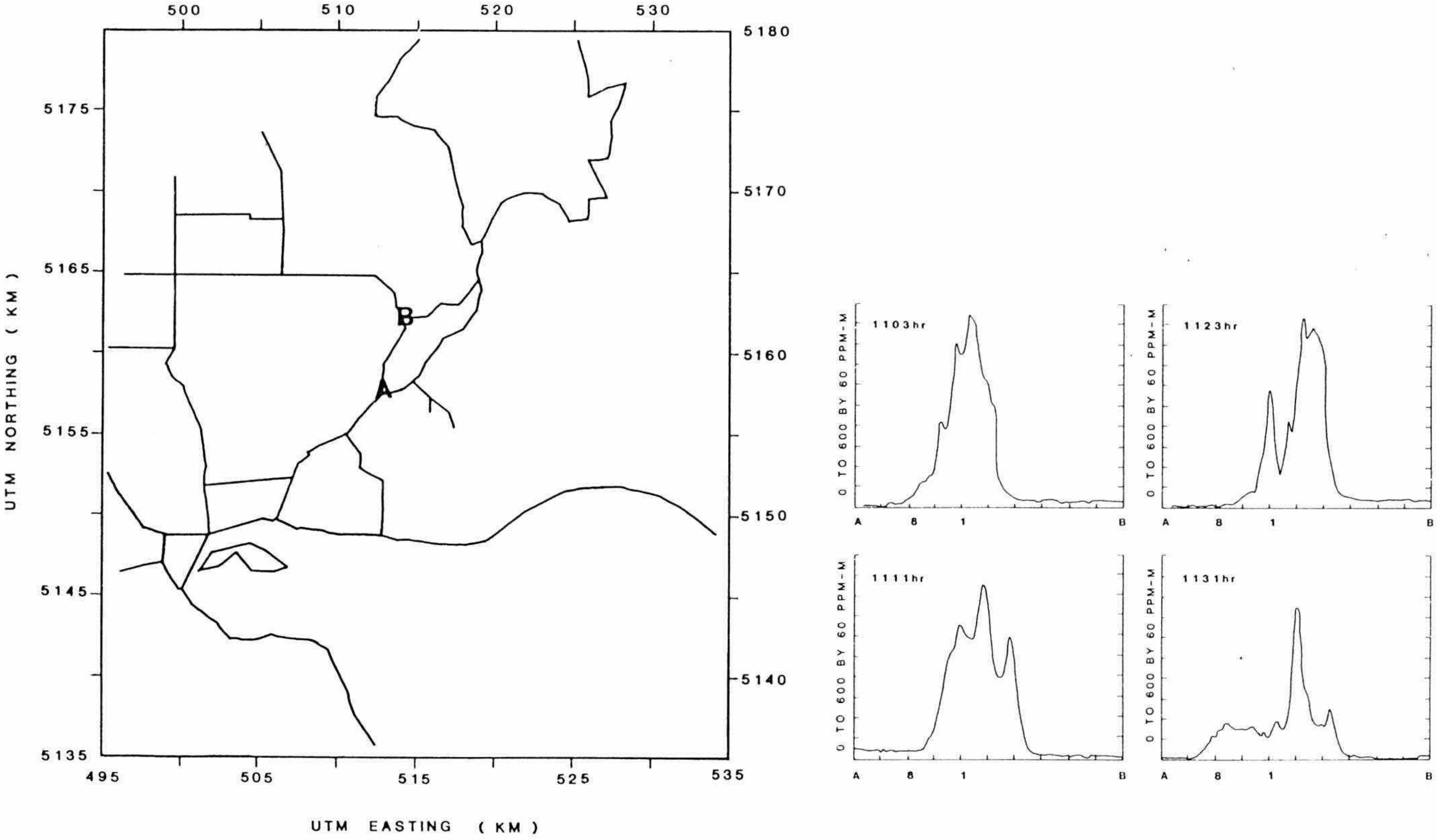
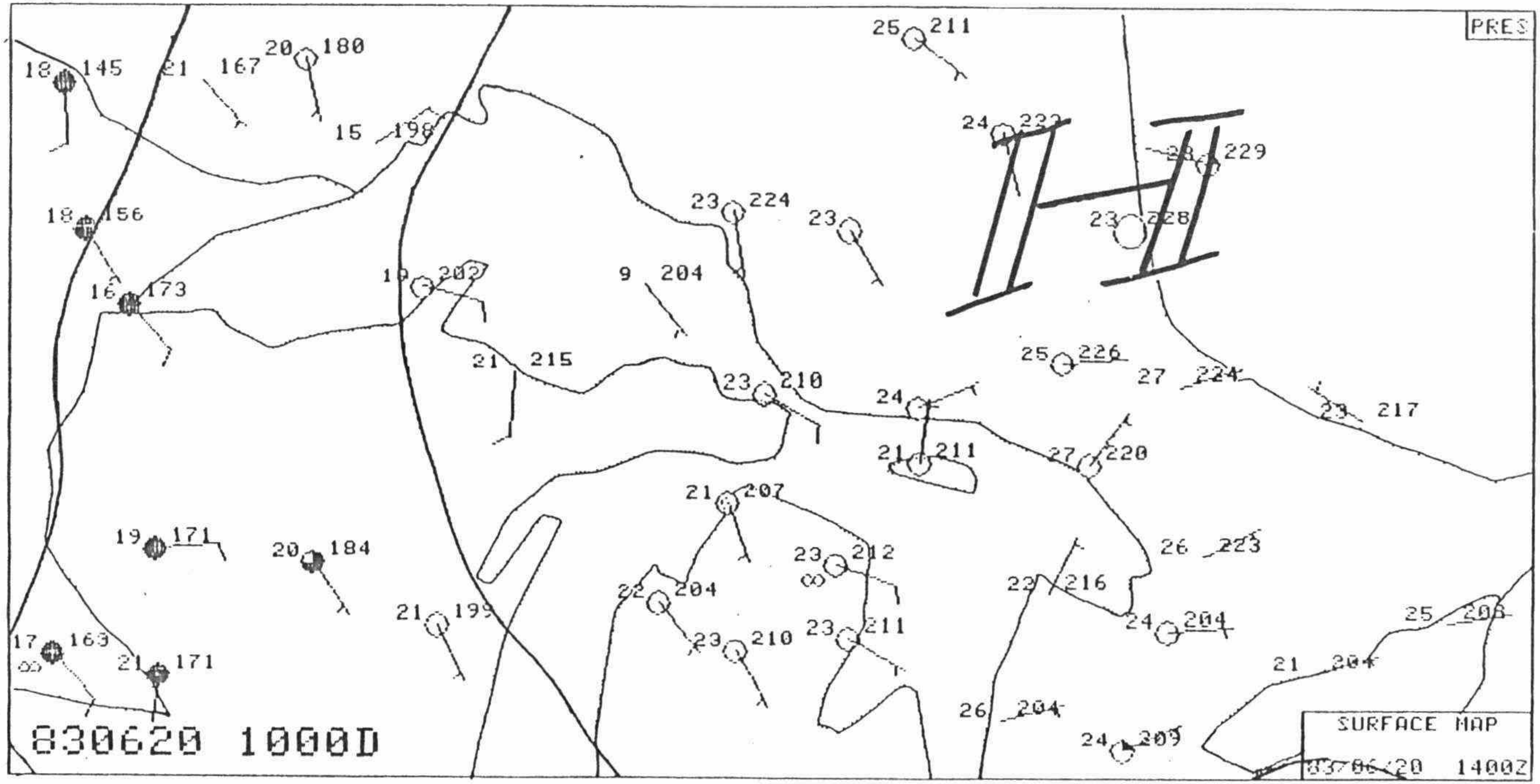


FIGURE 38



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 20

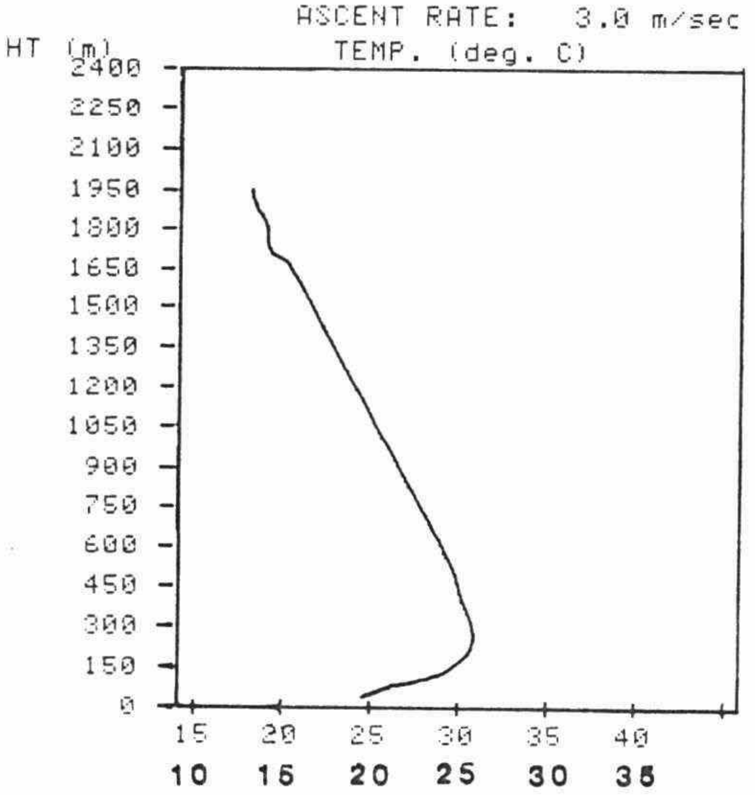
FIGURE 39



SURFACE WEATHER MAP AT 1400Z, JUNE 20, 1983.

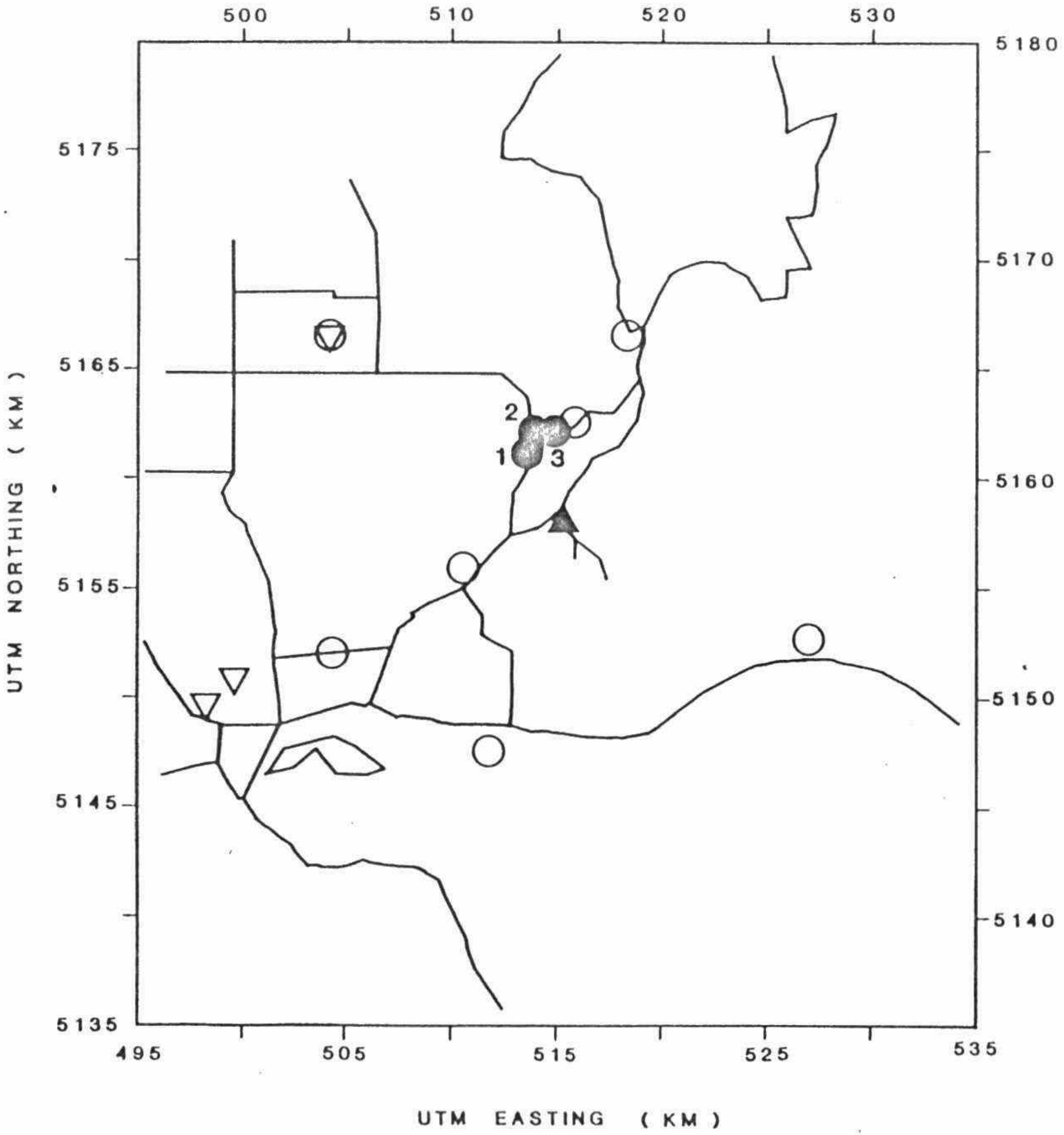
FIGURE 40

TEMPERATURE PROFILE WITH HEIGHT, JUNE 20, 1983.



```
NAME: FALCONBRIDGE_UA:C201A
LOC:  GARAGE
MET:  CLEAR WARM SLIGHT WINDS
ELEV:        300.0 m.                                GND TEMP:  25.1 deg.C(GND=20°C)
BASE:         40.0 m.                                BEARING : 134.0 deg.
```

FIGURE 41



MEASURED EXCEEDENCES

JUNE 21,1983

1/2 Hr. Standard:

Site 1	(MAMU 8)	1000-1030	.31 ppm
Site 1	(MAMU 8)	1030-1100	.38 ppm
Site 2	(MAMU 1)	1130-1200	.43 ppm
Site 3	(MAMU 2)	1130-1200	.34 ppm

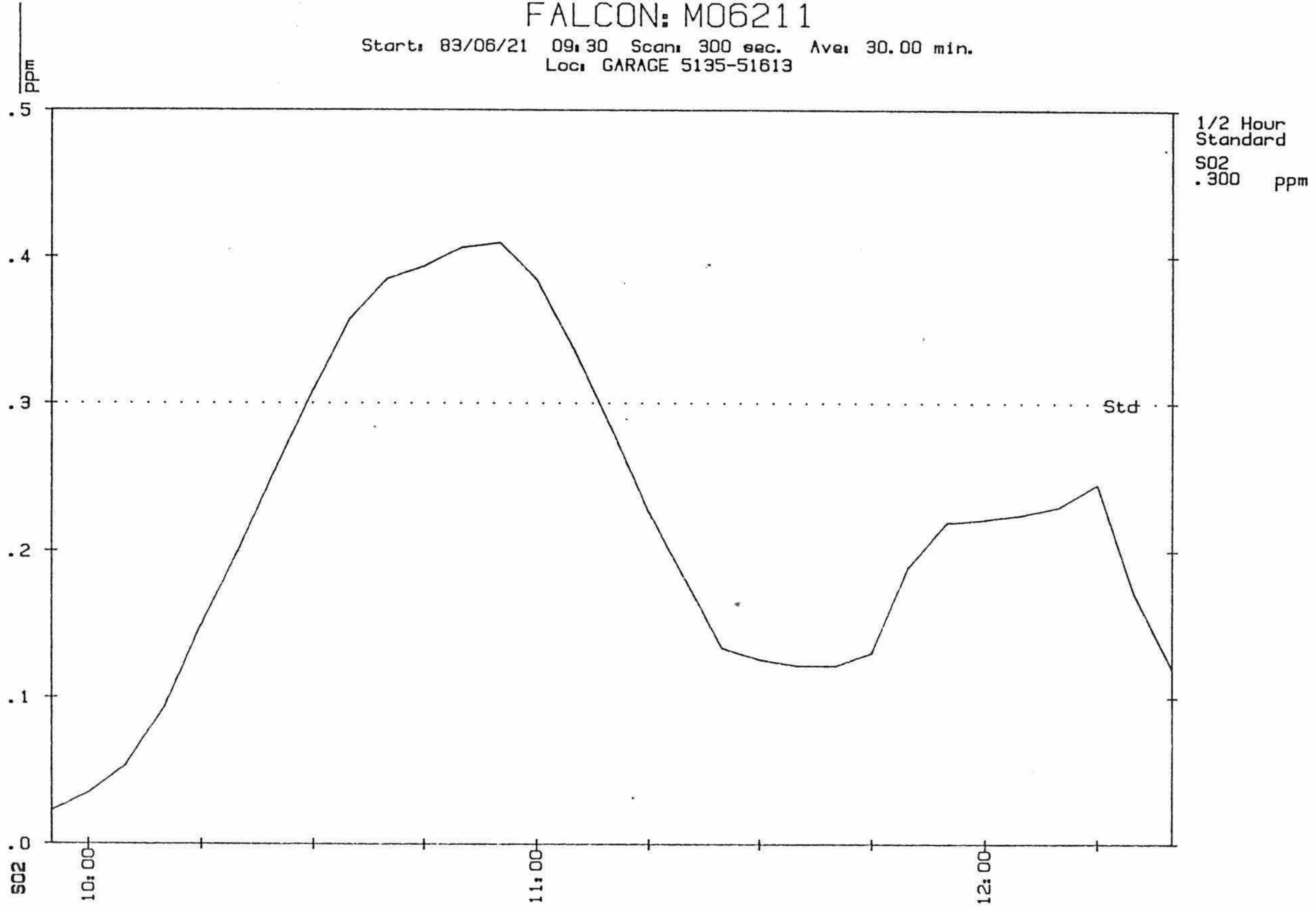
1 Hr. Criterion:

Site 1	(MAMU 8)	1000-1100	.35 ppm
Site 2	(MAMU 1)	1130-1230	.32 ppm

SYMBOLS:

○	SO_2 monitors (fixed or mobile)
▲	Falconbridge
▽	Met. stations (including MTC garage)
●	Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion
▼	Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 42



FALCON: M06211
Start: 83/06/21 09:30 Scan: 300 sec. Ave: 30.00 min.
Loc: GARAGE 5135-51613
ppm
.5
.4
.3
.2
.1
.0
SO2
10:00
11:00
12:00
Std
1/2 Hour
Standard
SO2
.300 ppm

FIGURE 43

FALCONBRIDGE: C212

Start: 83/06/21 10:34 Scan: 60 sec. Ave: 30.00 min.
Loc: Airport Rd. at Airport Pit (5149-51619)

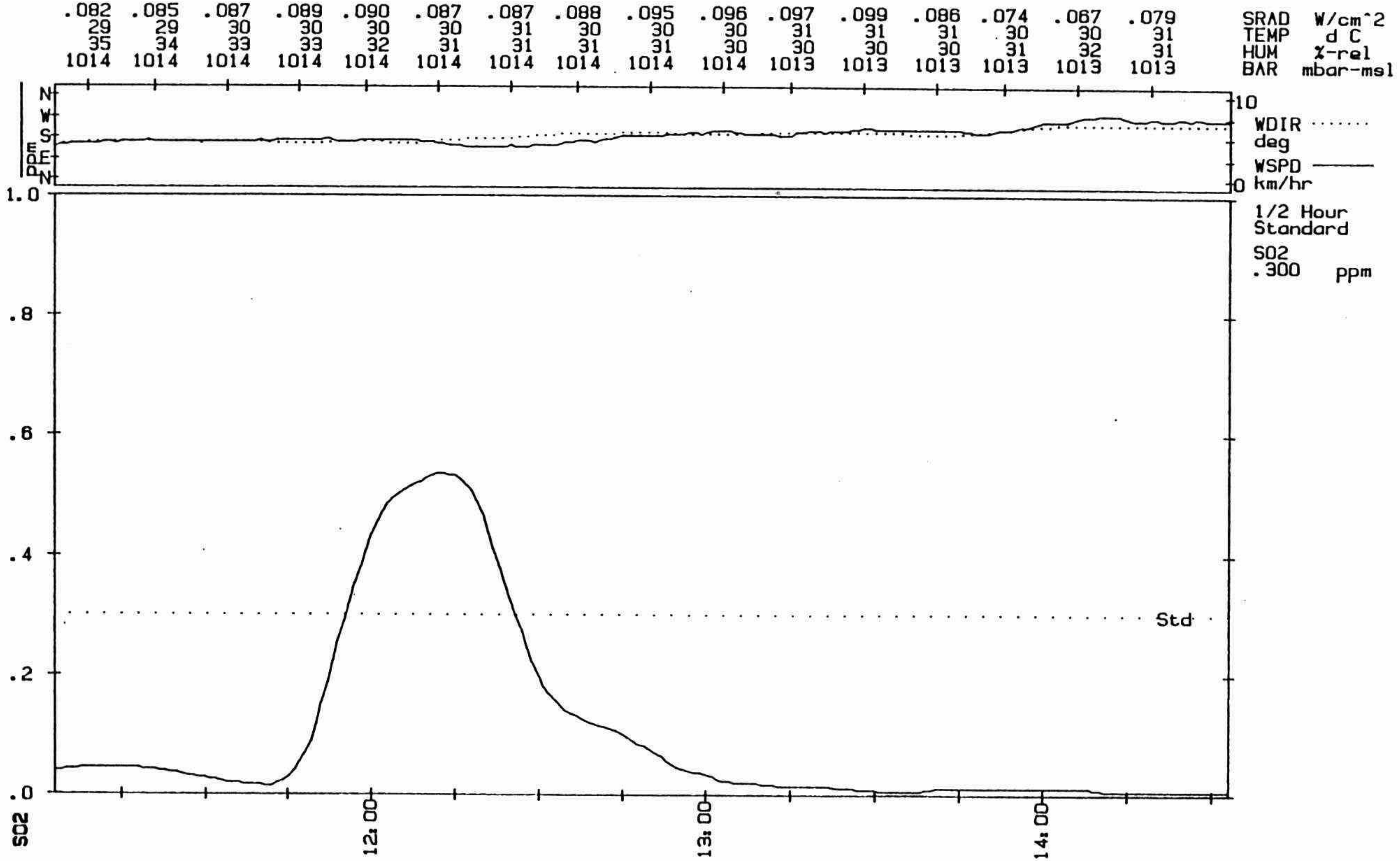


FIGURE 44

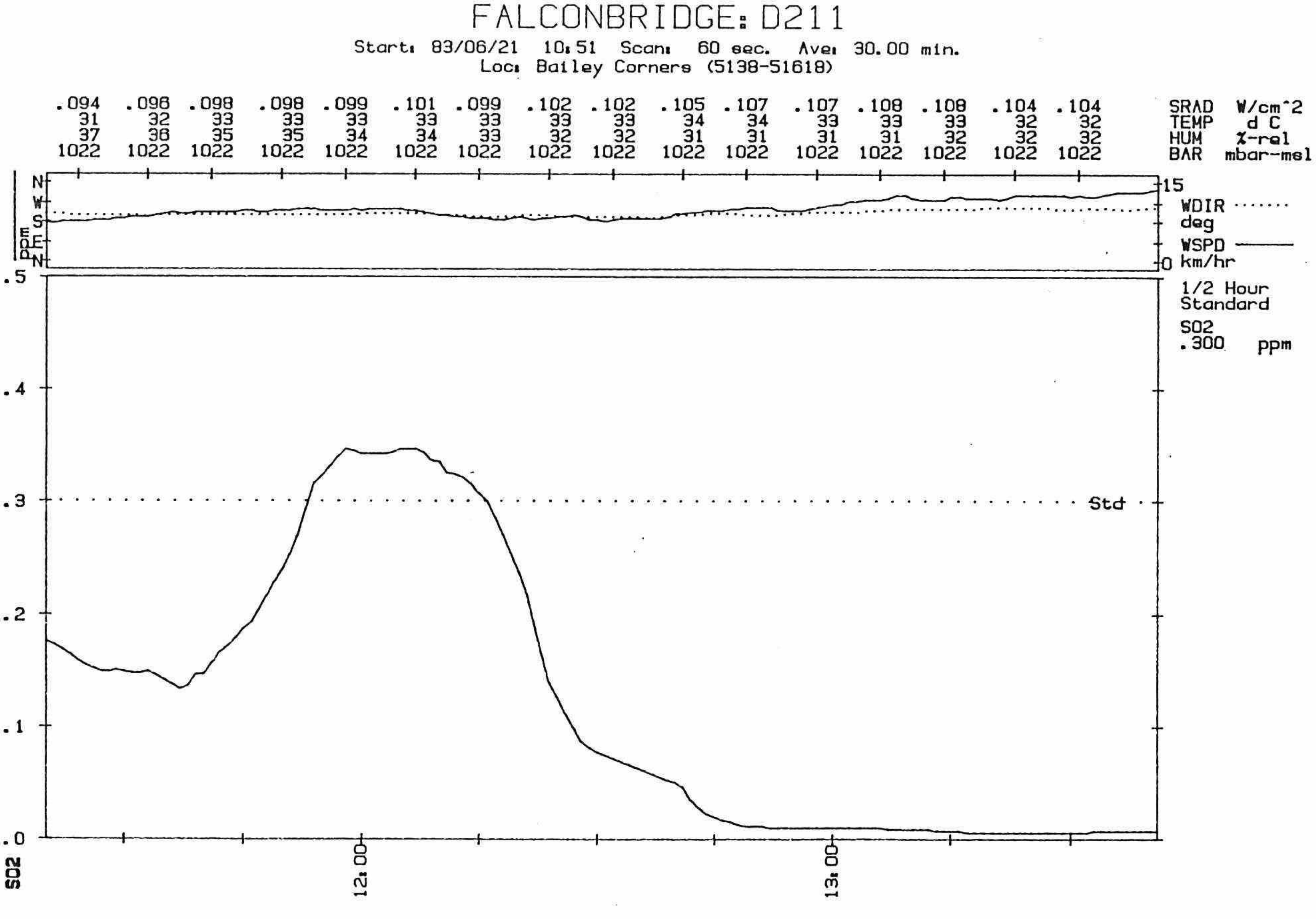
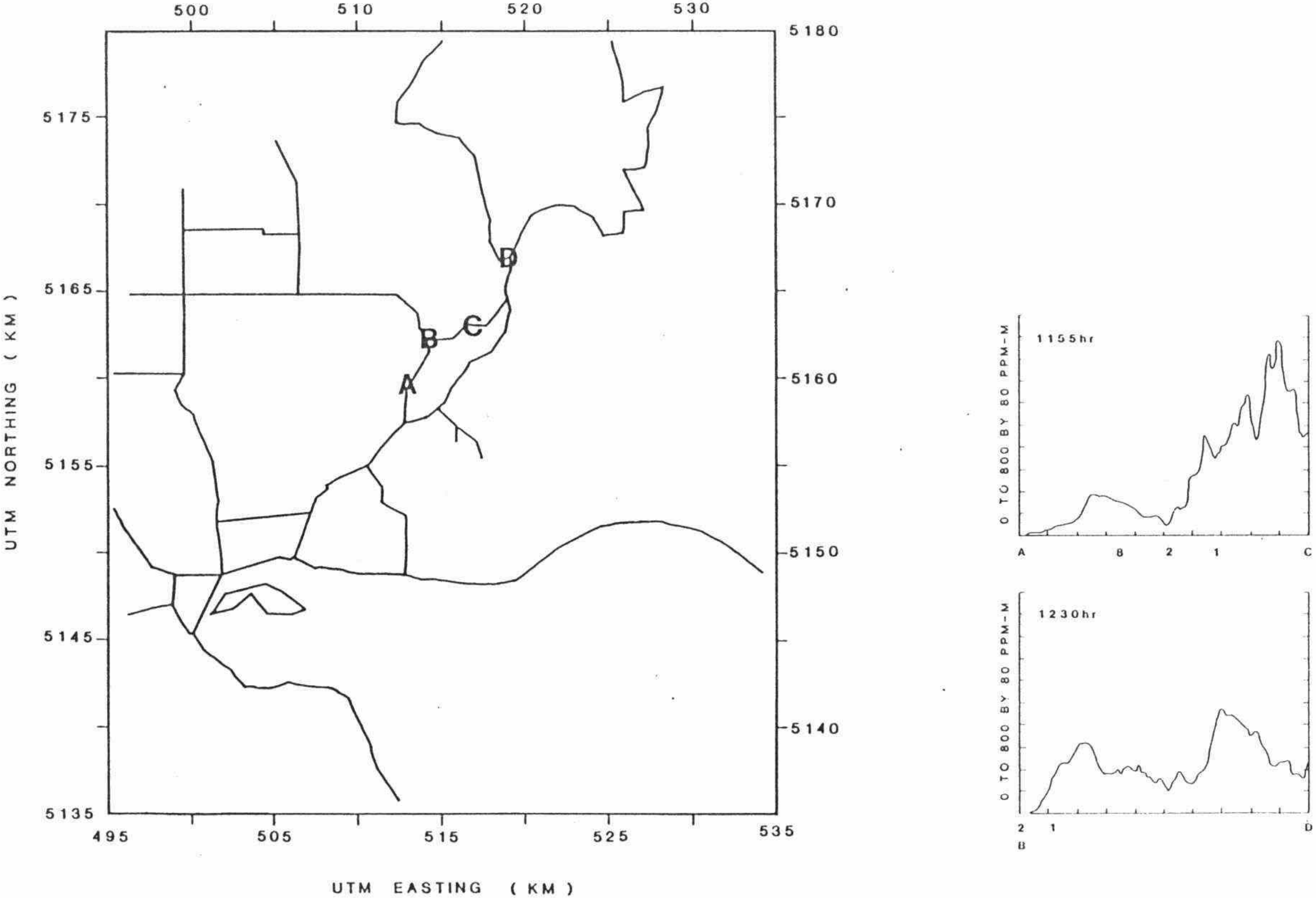
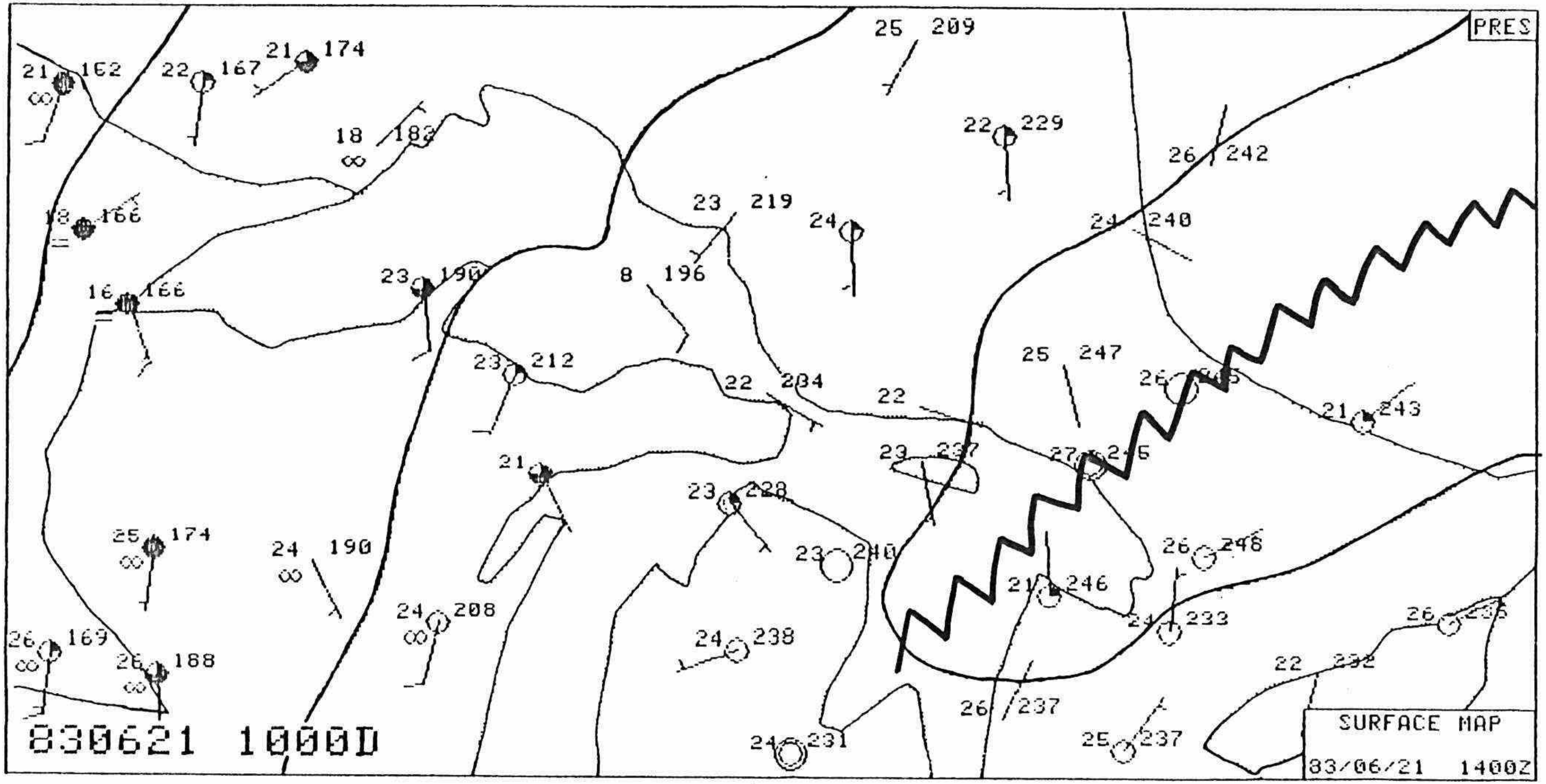

FALCONBRIDGE: D211
Start: 83/06/21 10:51 Scan: 60 sec. Ave: 30.00 min.
Loc: Bailey Corners (5138-51618)
.094 31 37 1022
.096 32 36 1022
.098 33 35 1022
.098 33 35 1022
.099 33 34 1022
.101 33 34 1022
.099 33 33 1022
.102 33 32 1022
.102 33 32 1022
.105 34 31 1022
.107 34 31 1022
.107 33 31 1022
.108 33 31 1022
.108 33 32 1022
.104 32 32 1022
.104 32 32 1022
SRAD W/cm^2
TEMP d C
HUM %-rel
BAR mbar-msl
N
W
S
E
N
15
0
WDIR ······
deg
WSPD ——
km/hr
1/2 Hour
Standard
SO2
.300 ppm
Std
.5
.4
.3
.2
.1
.0
SO2
12:00
13:00

FIGURE 45



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 21

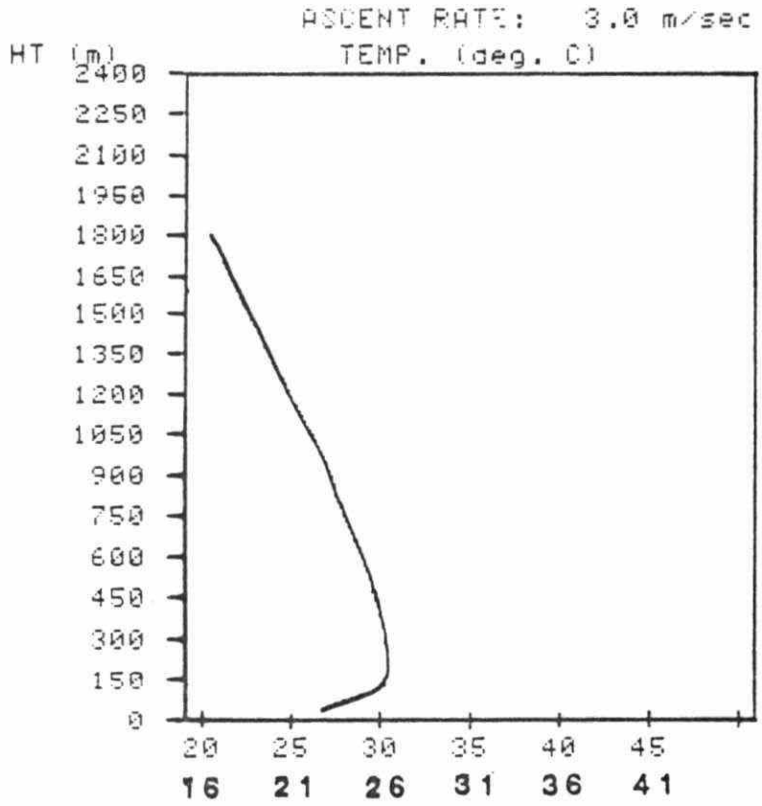
FIGURE 46



SURFACE WEATHER MAP AT 1400Z, JUNE 21, 1983.

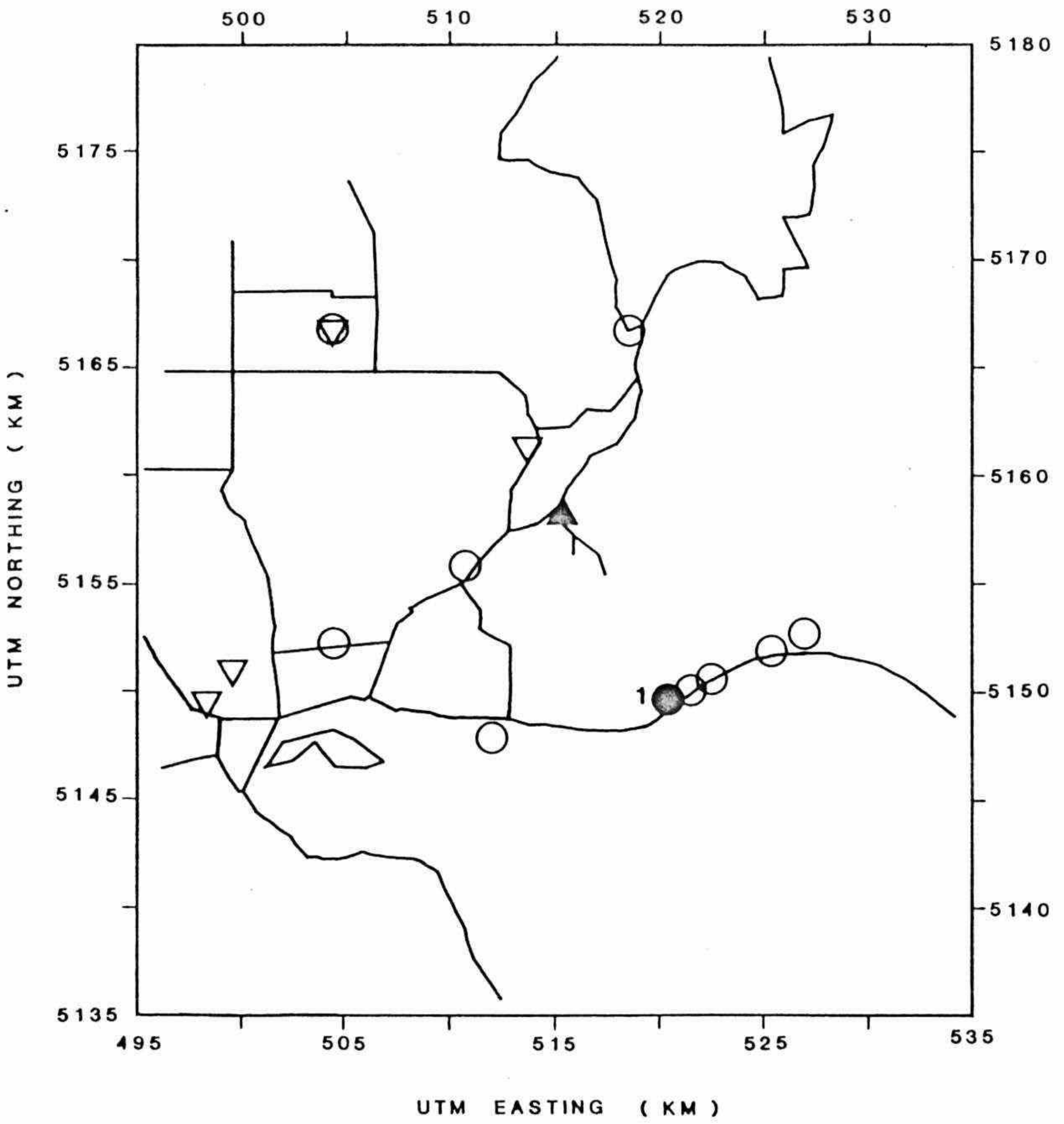
FIGURE 47

TEMPERATURE PROFILE WITH HEIGHT, JUNE 21, 1983.



```
NAME: FALCONBRIDGE_UA:C211A
LOC:  GAGARE
MET:  CLEAR LIGHT N WINDS     ,
ELEV:        300.0 m.                          GND TEMP:  24.6 deg.C(GND=21°C)
BASE:        110.0 m.                          BEARING : 134.0 deg.
```

FIGURE 48



MEASURED EXCEEDENCES

JUNE 24, 1983

1/2 Hr. Standard:
Site 1 (MAMU 8) 1025–1055 .31 ppm

1 Hr. Criterion:
no exceedences measured

SYMBOLS:

○ SO_2 monitors (fixed or mobile)

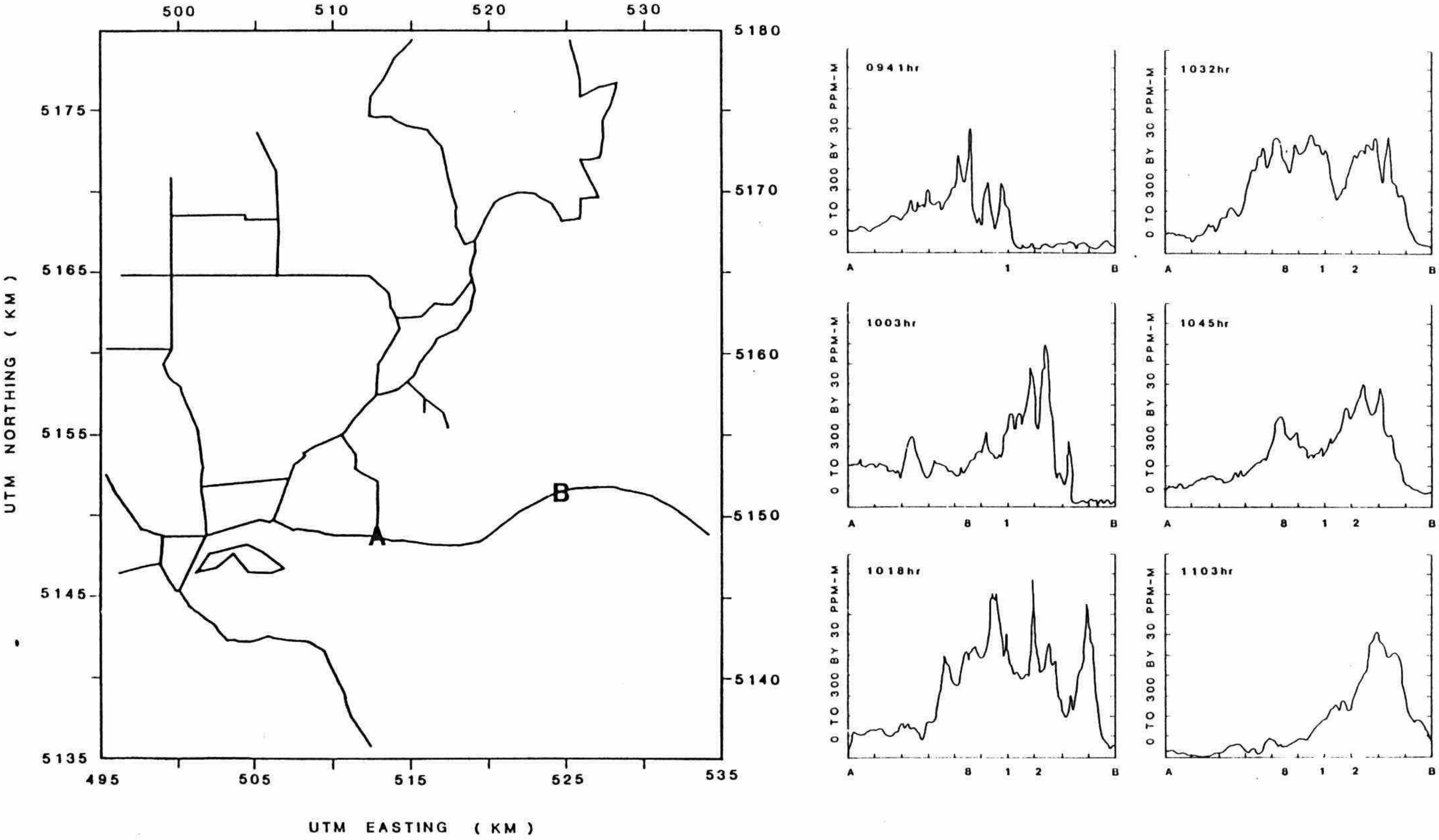
▲ Falconbridge

▽ Met. stations (including MTC garage)

● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion

▼ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 49



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 24

FIGURE 50

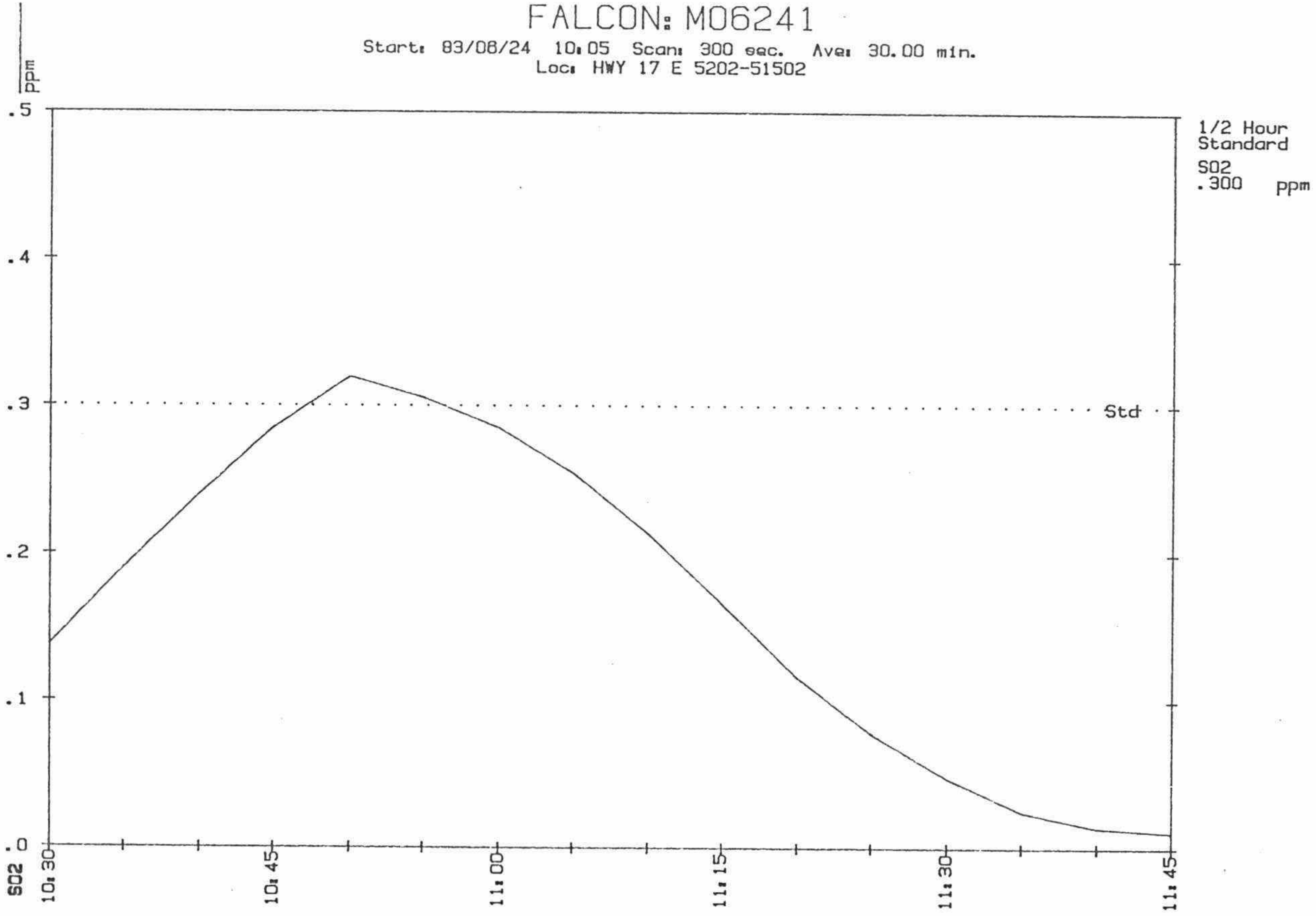
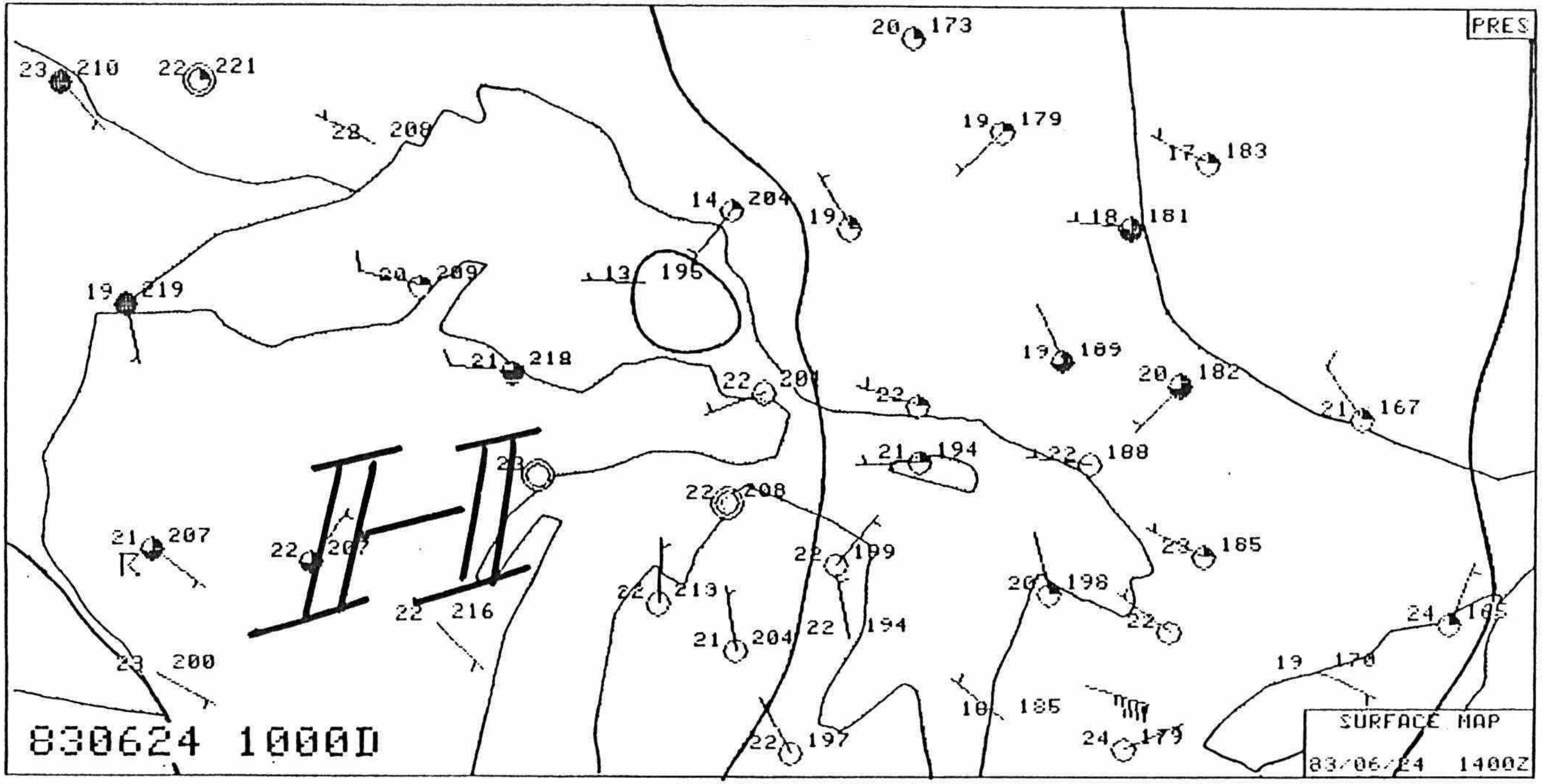

FALCON: M06241
Start: 83/08/24 10:05 Scan: 300 sec. Ave: 30.00 min.
Loc: HWY 17 E 5202-51502
ppm
.5
.4
.3
.2
.1
.0
SO2
10:30
10:45
11:00
11:15
11:30
11:45
1/2 Hour
Standard
SO2
.300 ppm
Std

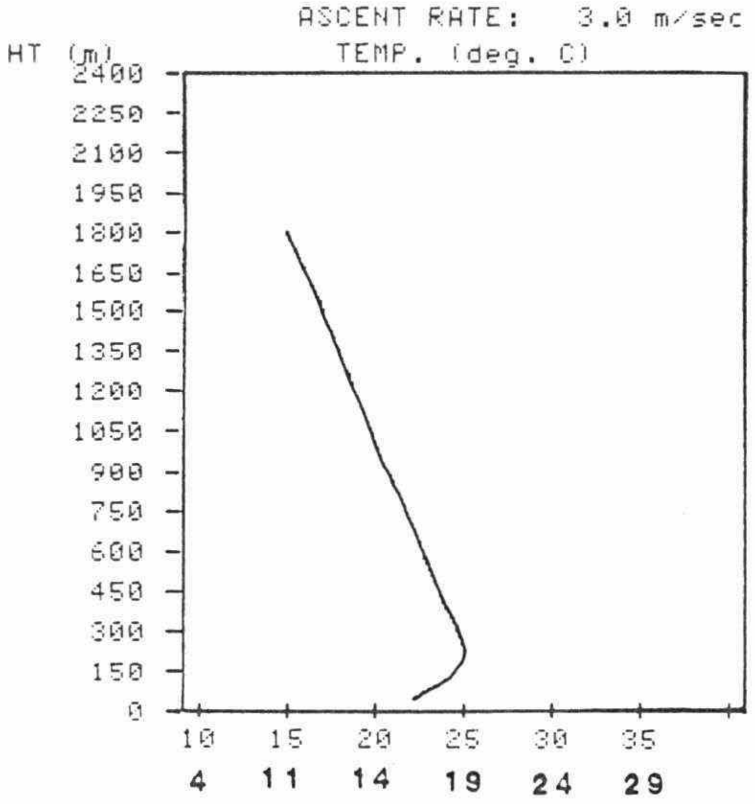
FIGURE 51



SURFACE WEATHER MAP AT 1400Z, JUNE 24, 1983.

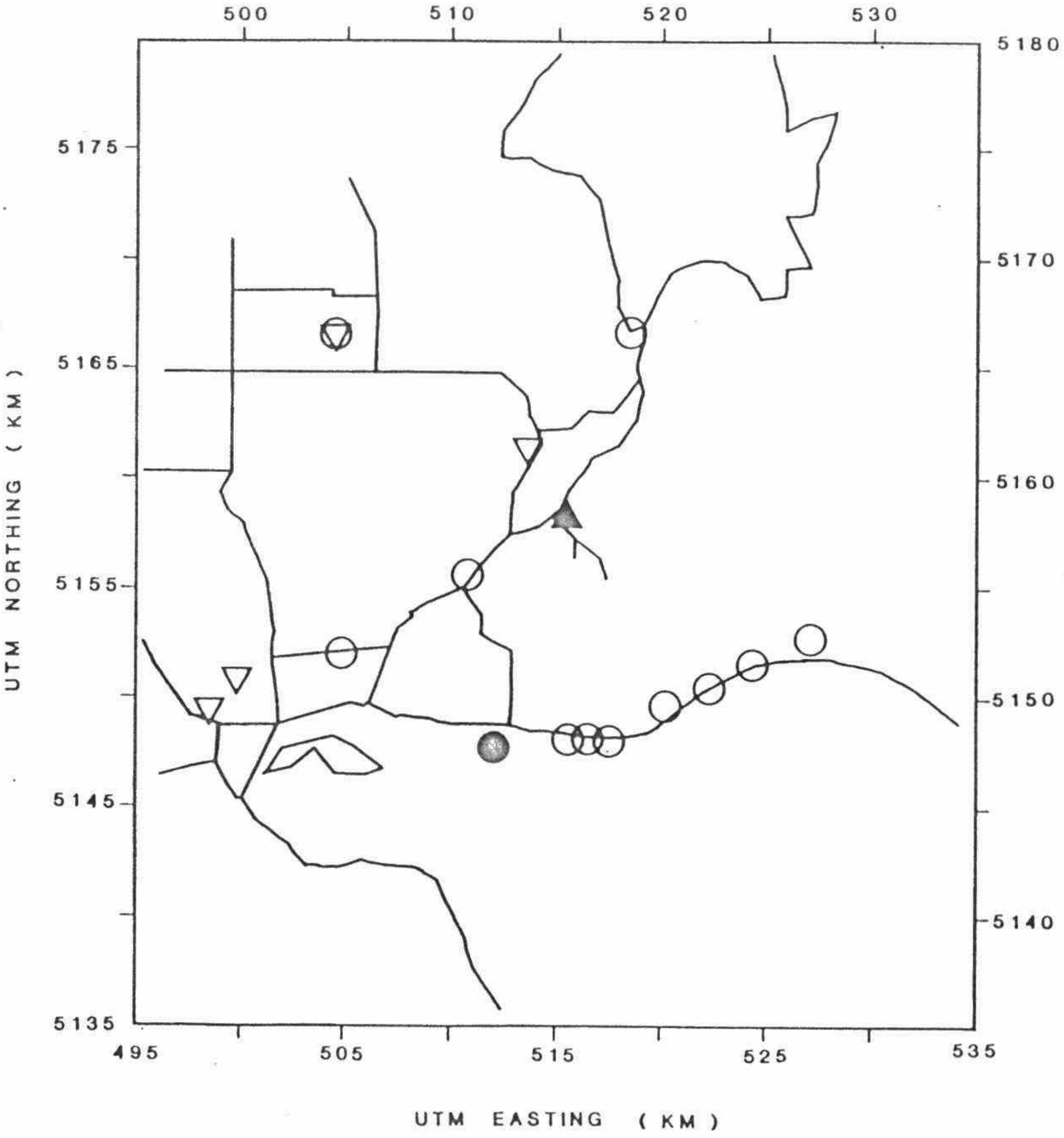
FIGURE 52

TEMPERATURE PROFILE WITH HEIGHT, JUNE 24, 1983.



```
NAME: FALCONBRIDGE_UA:C241A
LOC:  GARAGE
MET:  WARM SCATTERED NW WIND
ELEV:        300.0 m.
BASE:         70.0 m.                    GND TEMP:  20.7 deg.C(GND=14°C)
                                         BEARING : 134.0 deg.
```

FIGURE 53



MEASURED EXCEEDENCES

JUNE 25, 1983

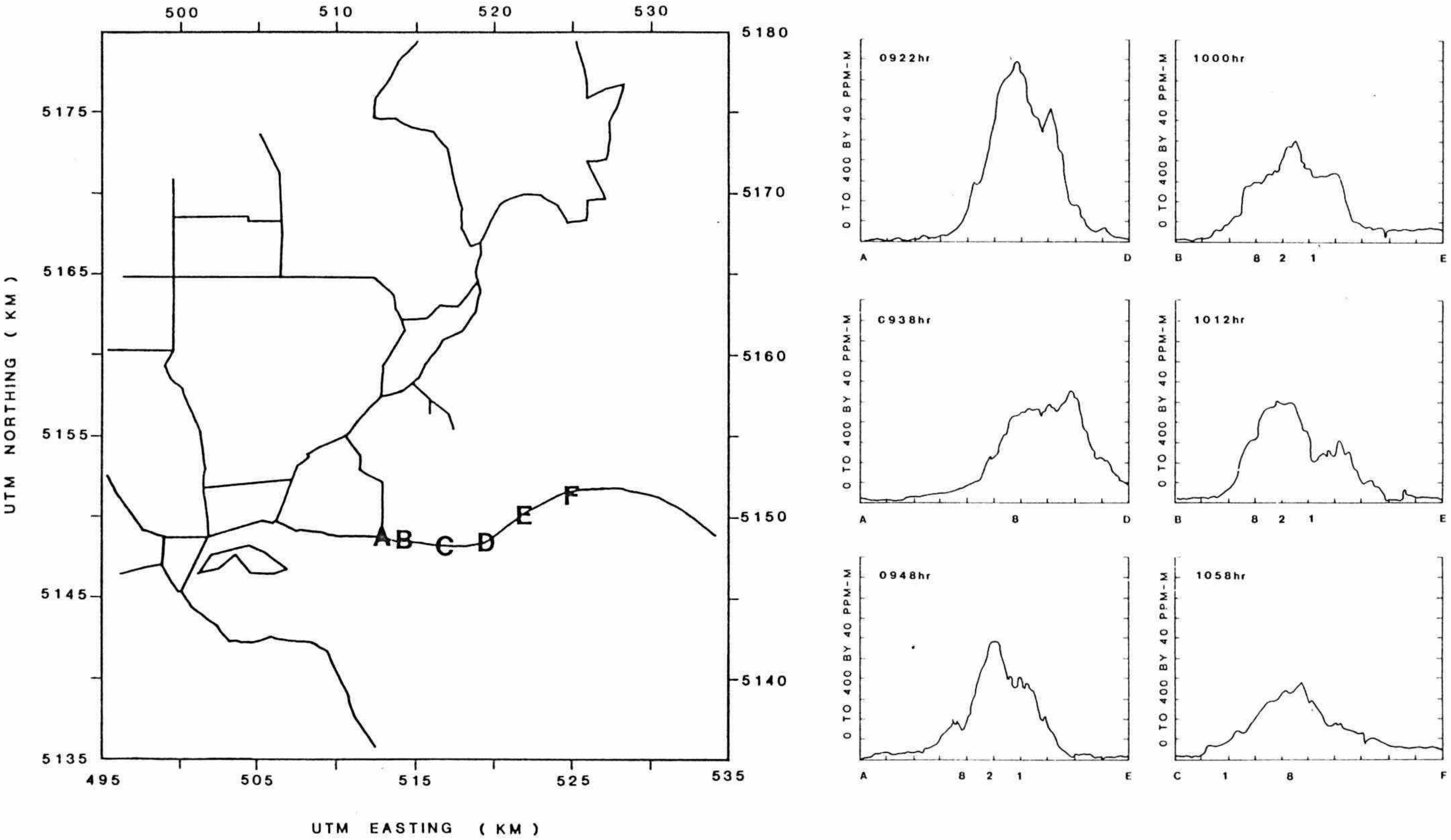
1/2 Hr. Standard:
Site 1 (CONISTON) 805-835 .37 ppm

1 Hr. Criterion:
Site 1 (CONISTON) 800-900 .29 ppm

SYMBOLS:

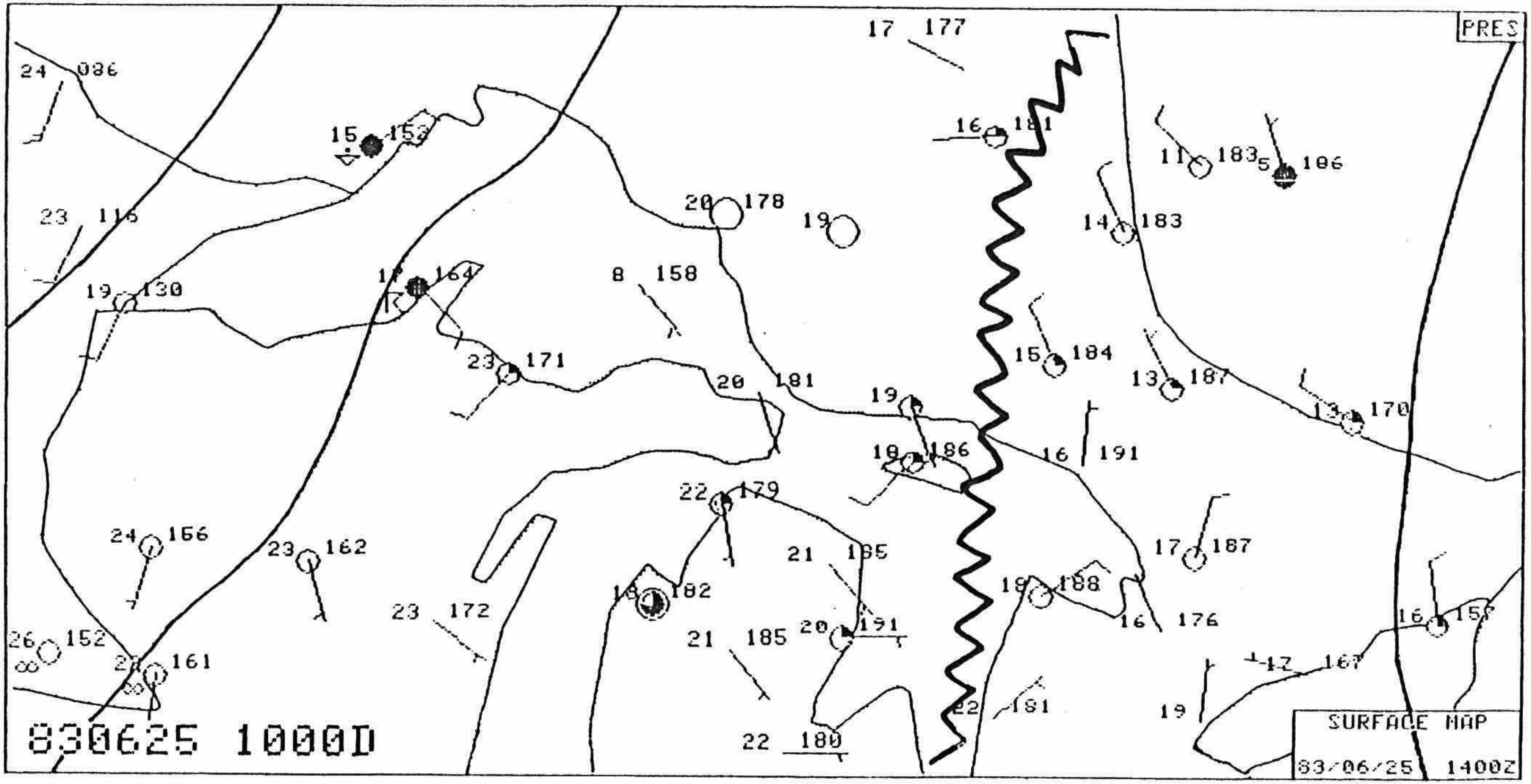
- ○ SO_2 monitors (fixed or mobile)
- ▲ Falconbridge
- ▽ Met. stations (including MTC garage)
- ● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion
- ⊽ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 54



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 25

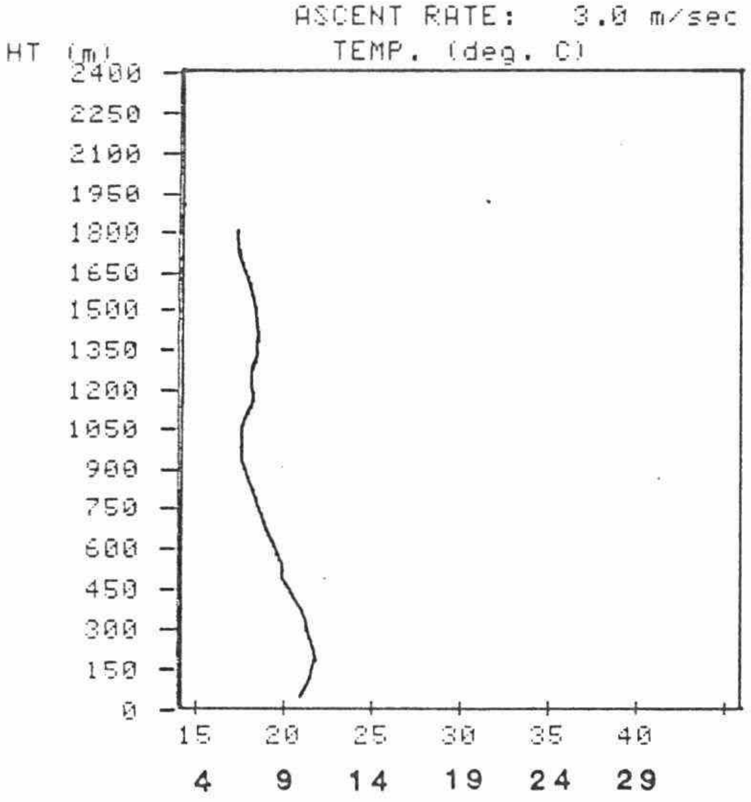
FIGURE 55



SURFACE WEATHER MAP AT 1400Z, JUNE 25, 1983.

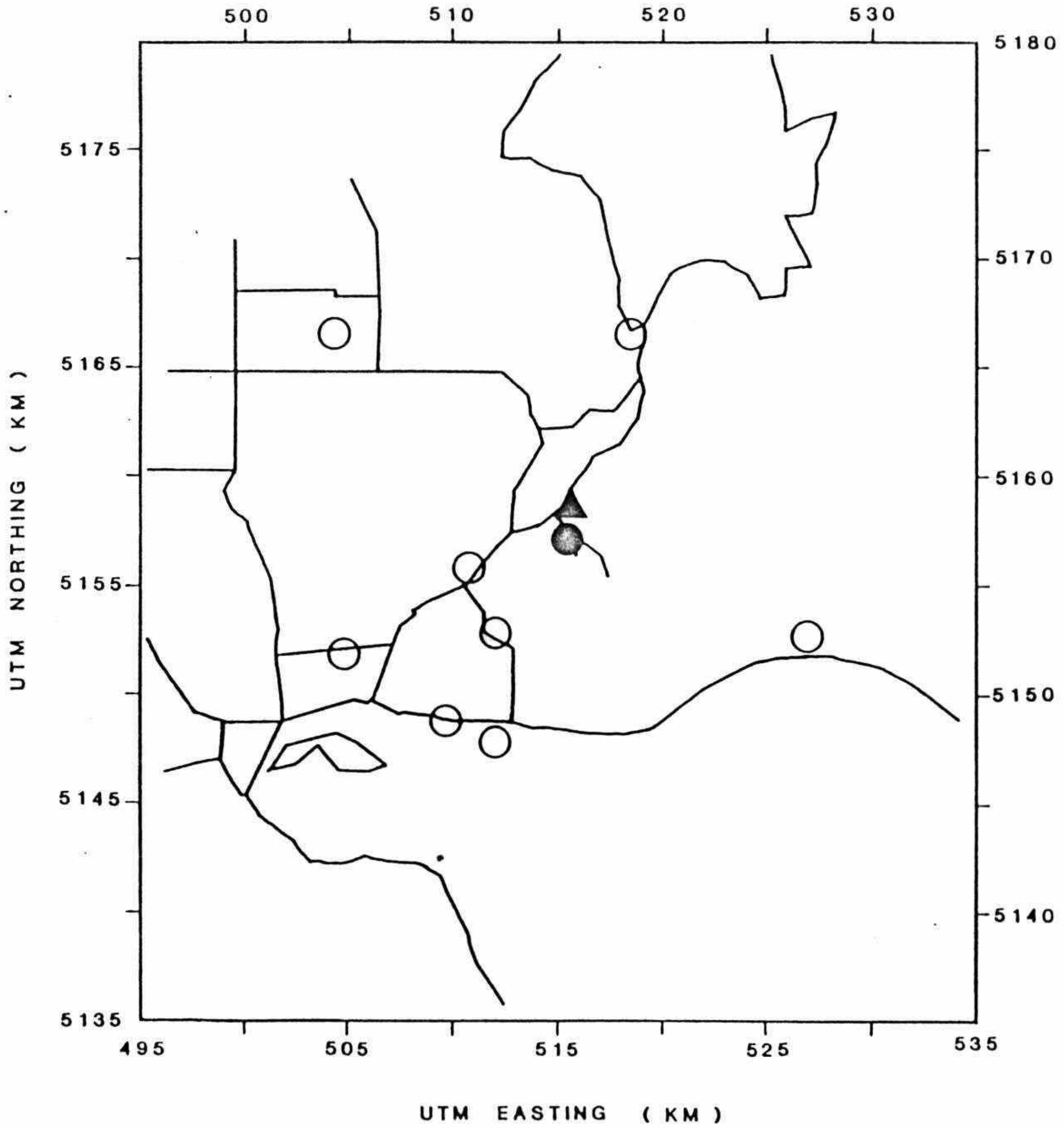
FIGURE 56

TEMPERATURE PROFILE WITH HEIGHT, JUNE 25, 1983.



```
NAME: FALCONBRIDGE_UA:C251A
LOC:  GARAGE
MET:  CLEAR CALM NW WINDS
ELEV:         300.0 m.                      GND TEMP:  20.9 deg.C (GND=9°C)
BASE:          40.0 m.                      BEARING : 134.0 deg.
```

FIGURE 57



MEASURED EXCEEDENCES

JUNE 27, 1983

1/2 Hr. Standard:

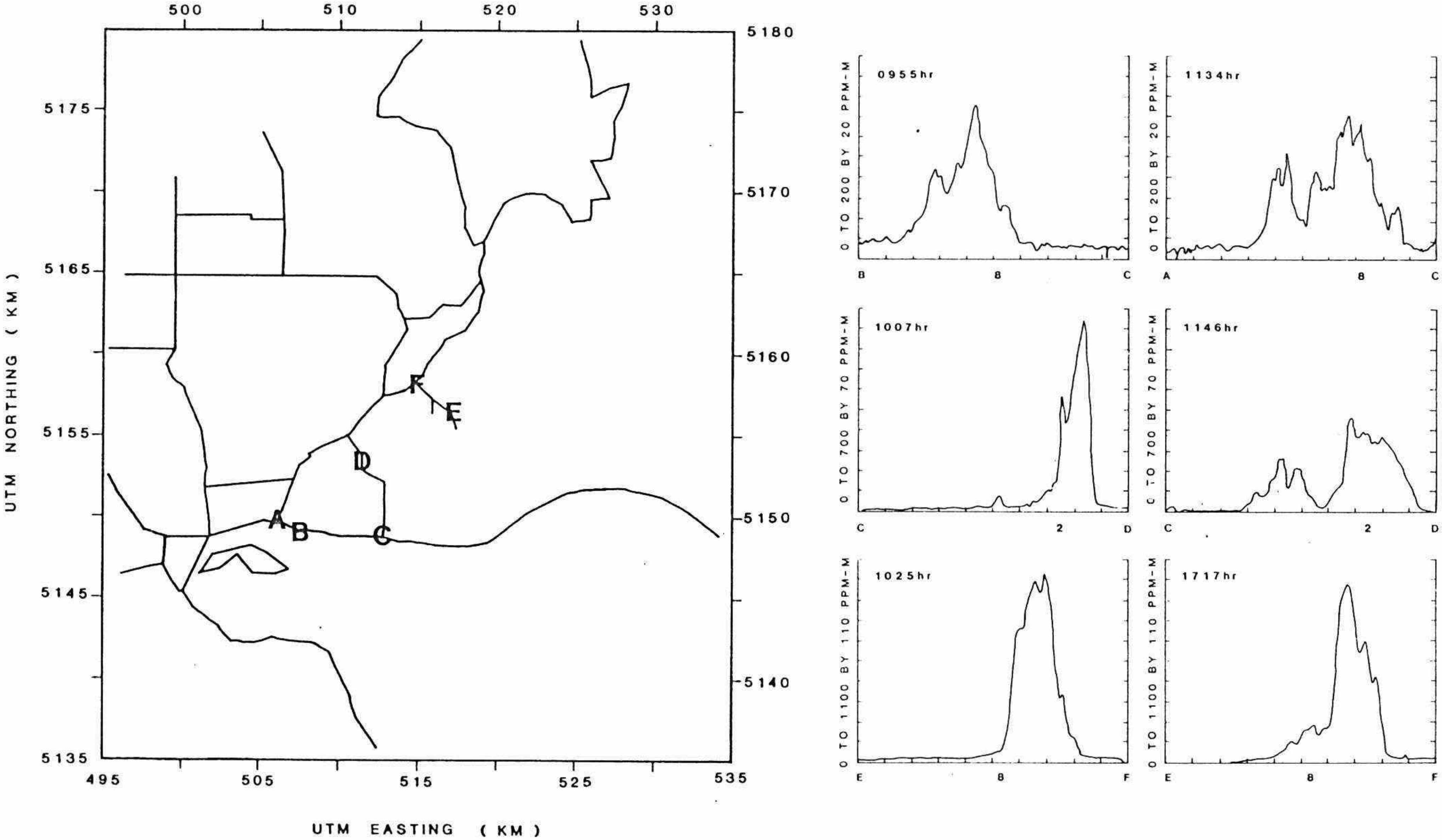
Site 1	**(MAMU 1)**	**1110-1140**	**.31 ppm**
Site 1	**(MAMU 1)**	**1605-1635**	**.33 ppm**

1 Hr. Criterion:
no exceedences measured

SYMBOLS:

○	SO_2 monitors (fixed or mobile)
▲	Falconbridge
▽	Met. stations (including MTC garage)
●	Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion
▼	Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 58



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 27

FIGURE 59

FALCONBRIDGE: C273

Start: 83/06/27 09:32 Scan: 60 sec. Ave: 30.00 min.
Loc: Norway Lake in Happy Valley (5146-51567)

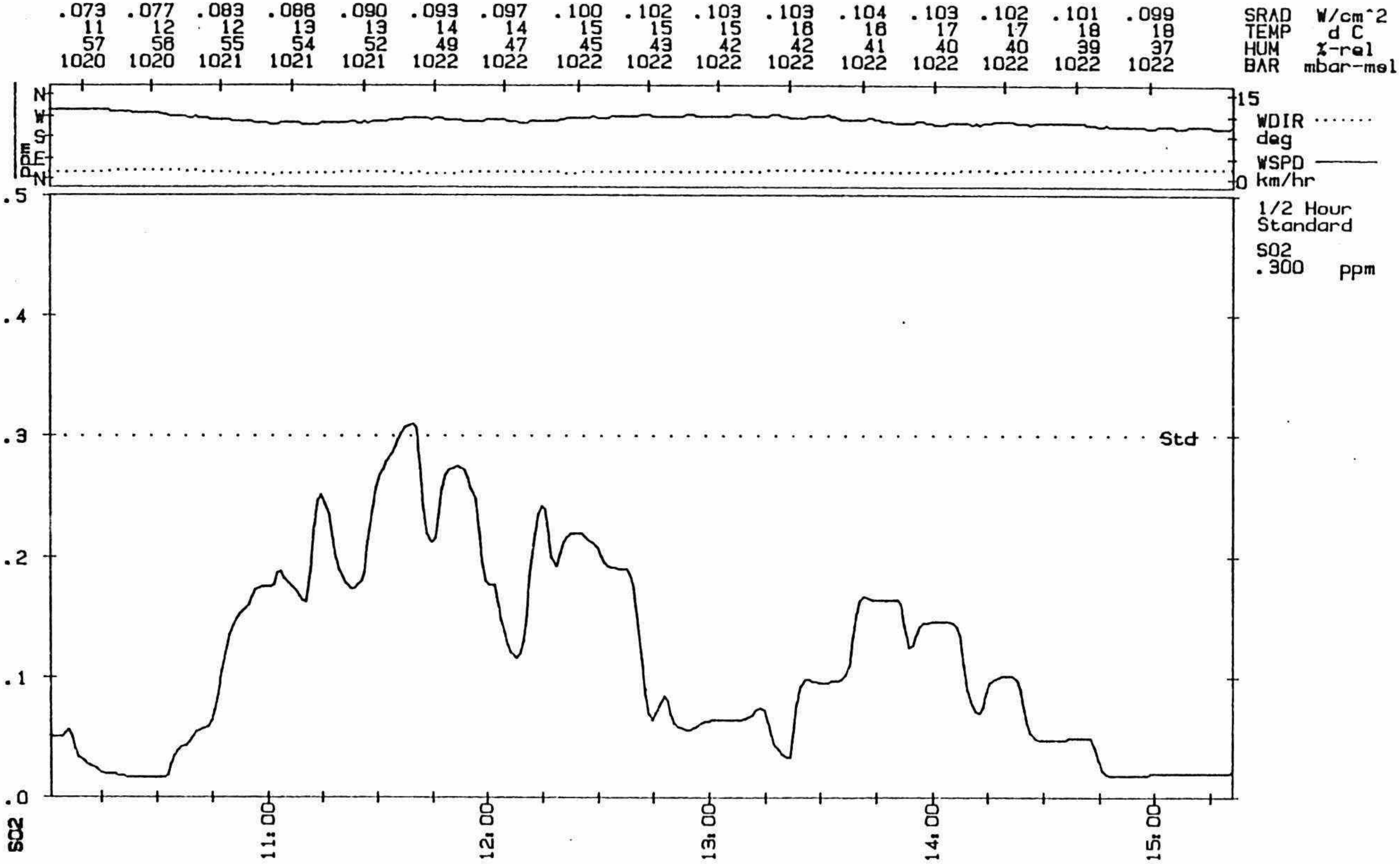


FIGURE 60

FALCONBRIDGE: C274

Start: 83/06/27 15:28 Scan: 60 sec. Ave: 30.00 min.
Loc: Norway Lake in Happy Valley (5146-51567)

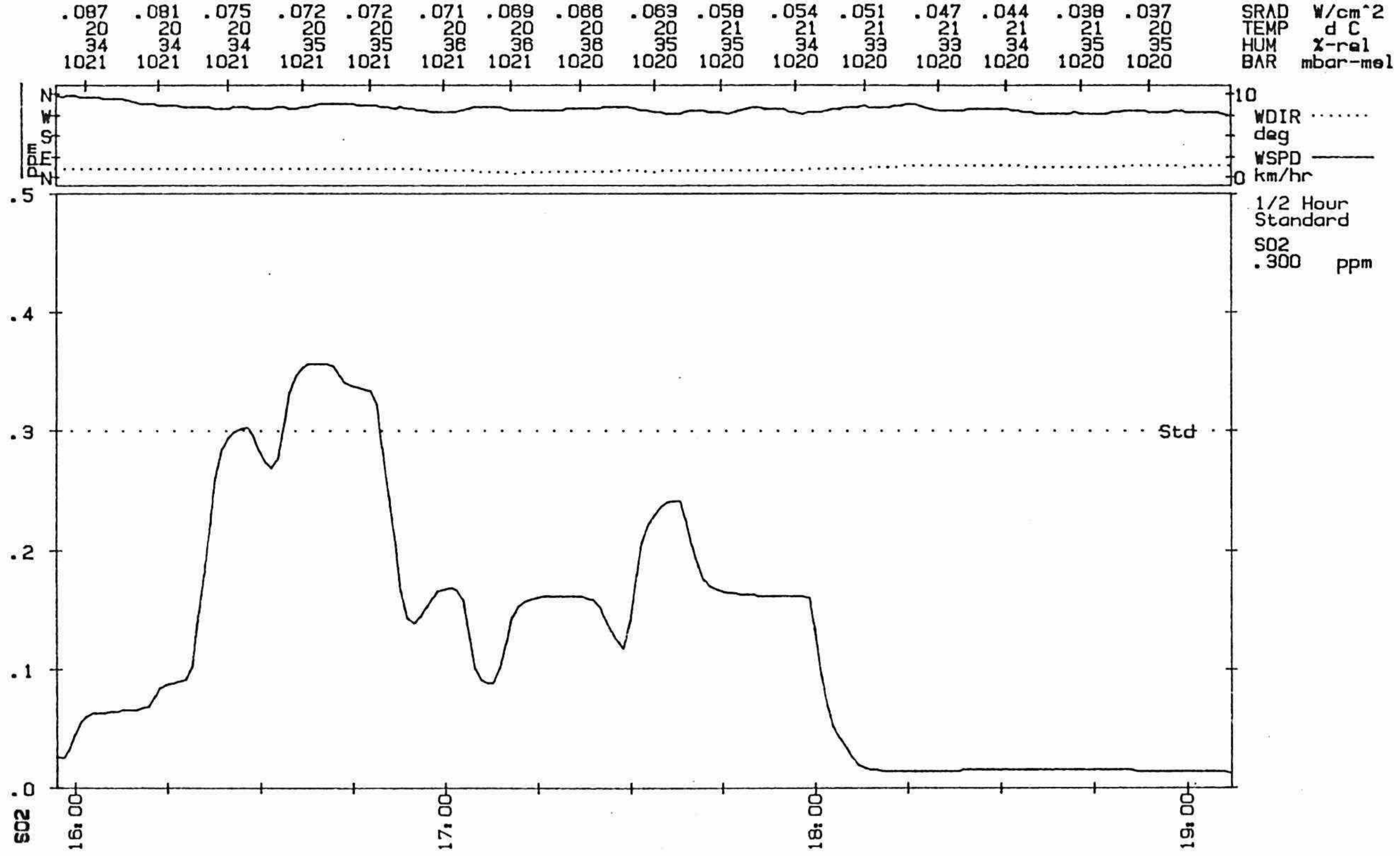


FIGURE 61

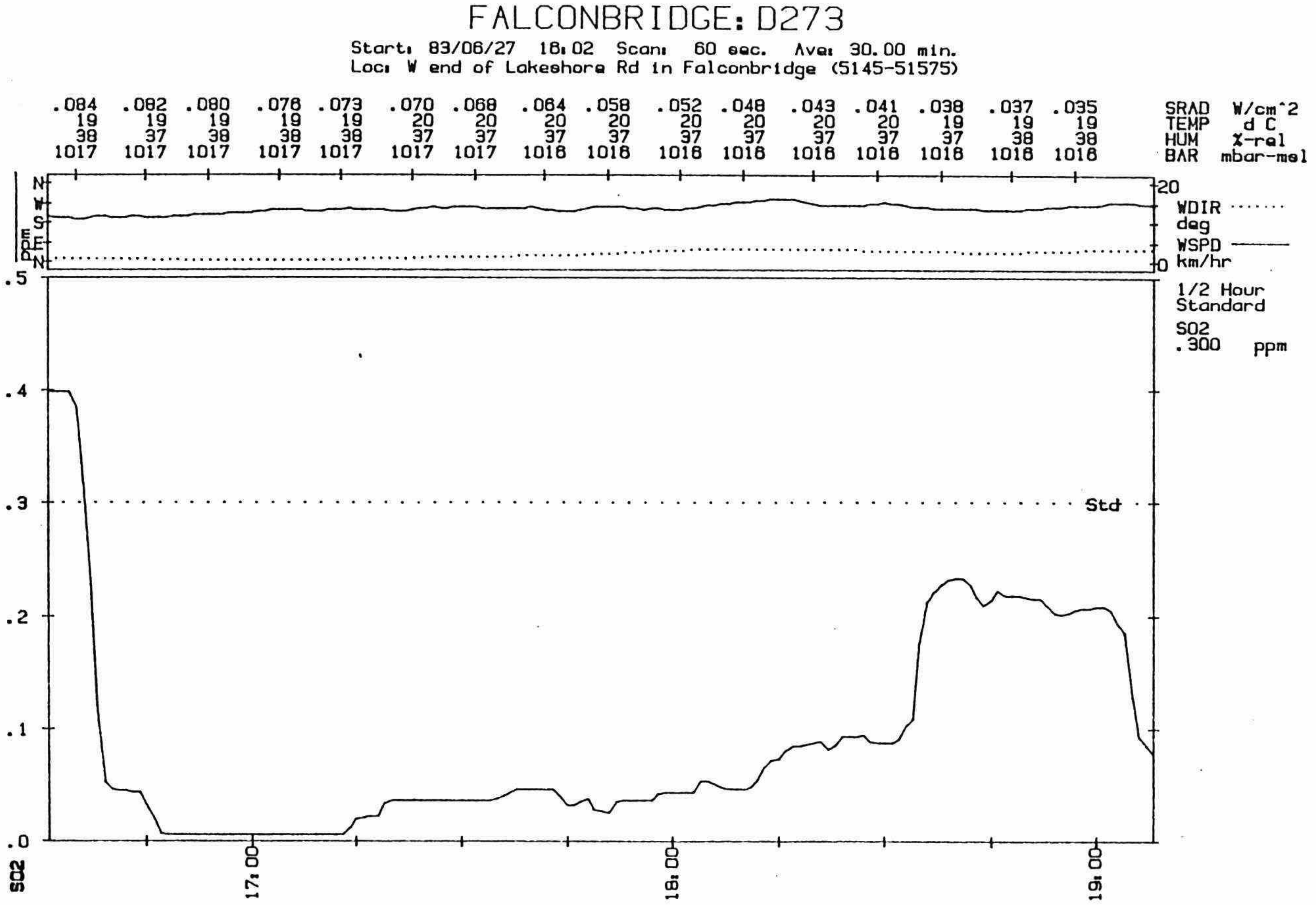
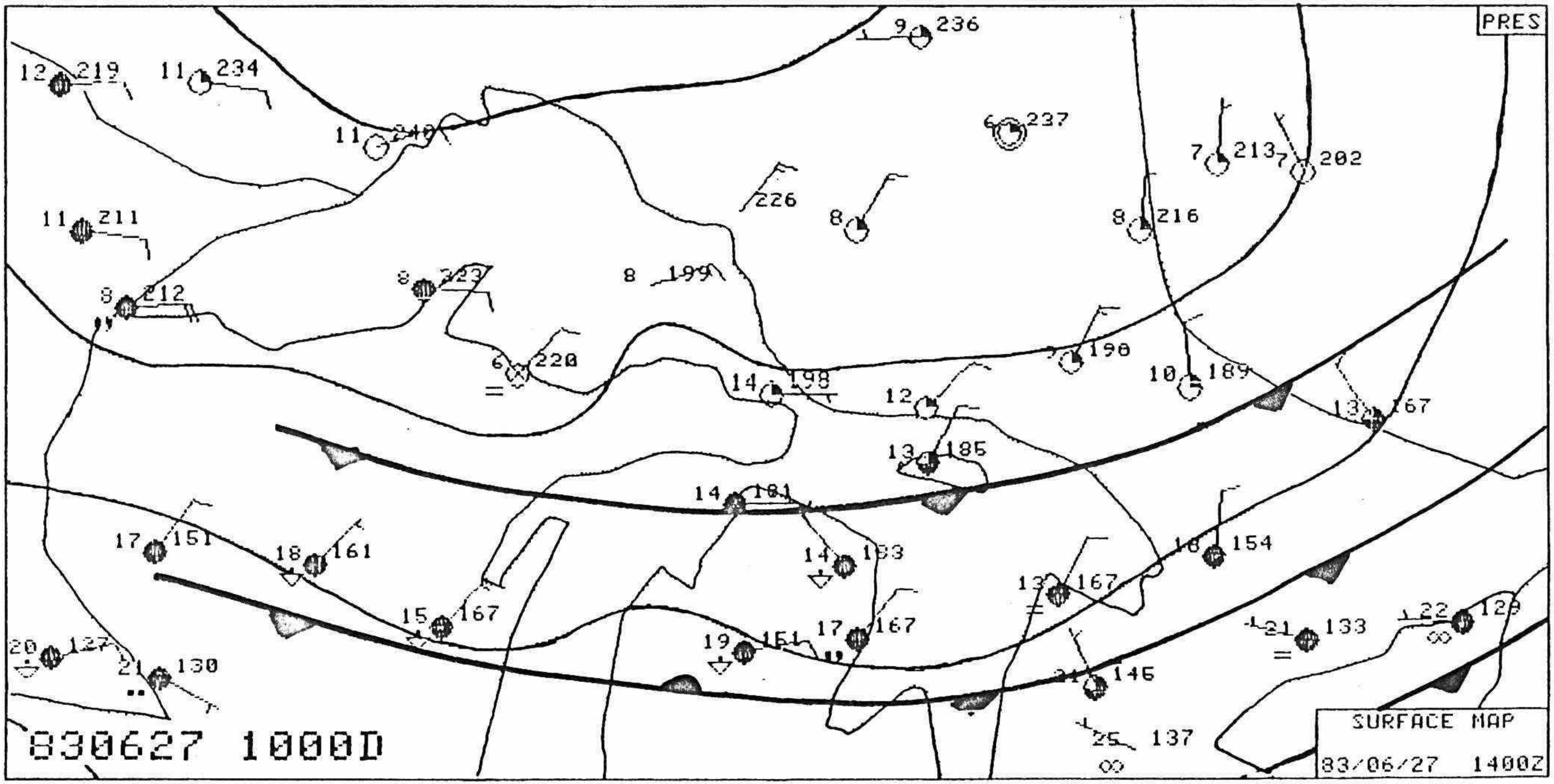

FALCONBRIDGE: D273
Start: 83/06/27 16:02 Scan: 60 sec. Ave: 30.00 min.
Loc: W end of Lakeshore Rd in Falconbridge (5145-51575)
.084 19 38 1017
.082 19 37 1017
.080 19 38 1017
.078 19 38 1017
.073 19 38 1017
.070 20 37 1017
.068 20 37 1017
.064 20 37 1018
.058 20 37 1018
.052 20 37 1018
.048 20 37 1018
.043 20 37 1018
.041 20 37 1018
.038 19 37 1018
.037 19 38 1018
.035 19 38 1018
SRAD W/cm^2
TEMP d C
HUM %-rel
BAR mbar-msl
N
W
S
E
N
20
0
WDIR
deg
WSPD
km/hr
1/2 Hour Standard
SO2
.300 ppm
Std
.5
.4
.3
.2
.1
.0
SO2
17:00
18:00
19:00

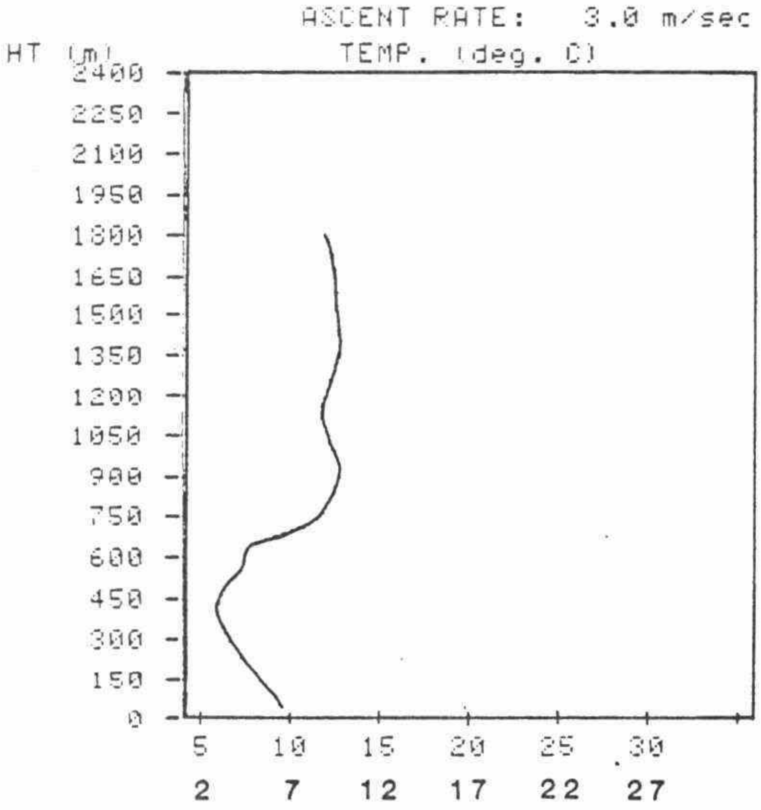
FIGURE 62



SURFACE WEATHER MAP AT 1400Z, JUNE 27, 1983.

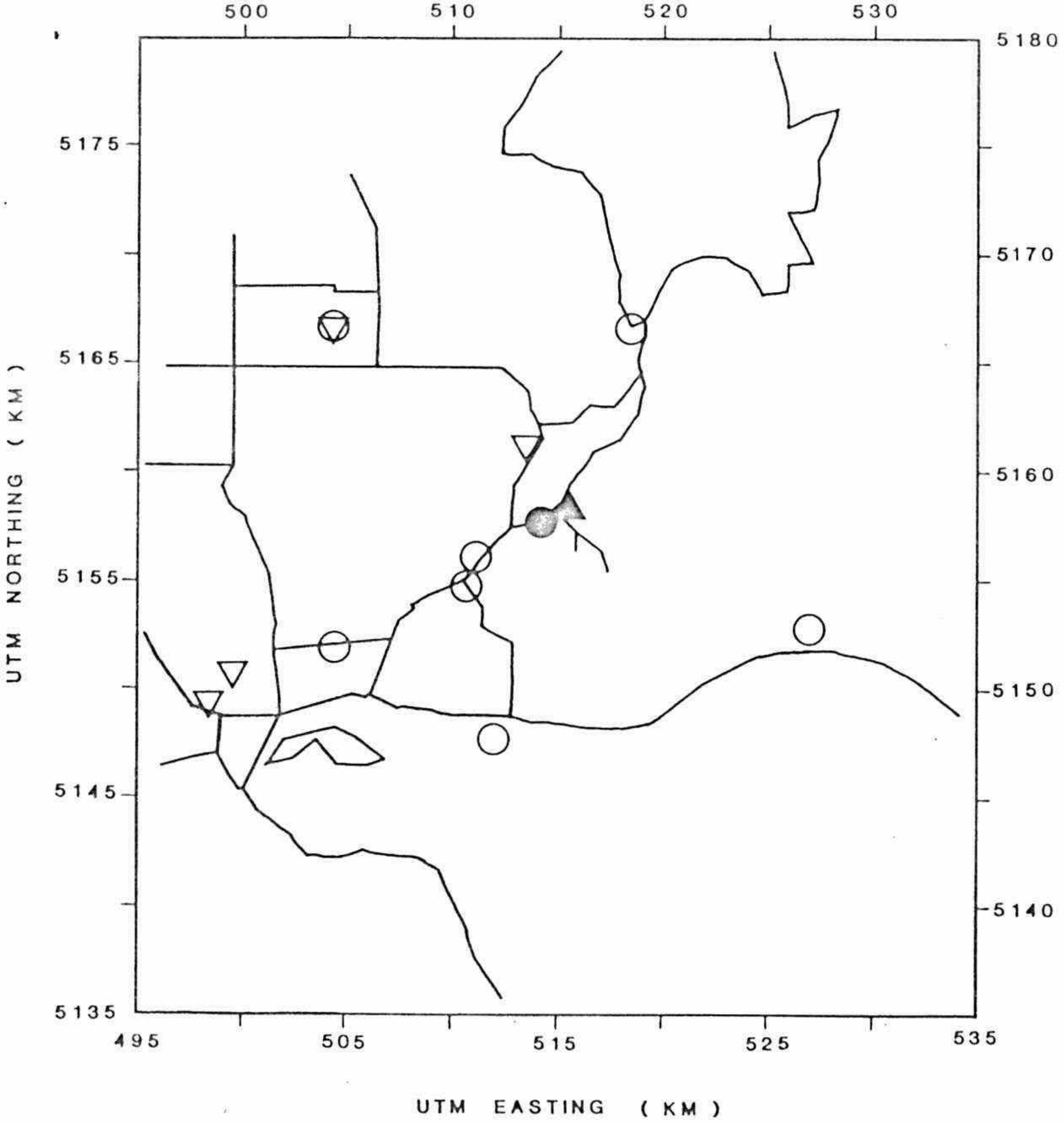
FIGURE 63

TEMPERATURE PROFILE WITH HEIGHT, JUNE 27, 1983.



```
NAME: FALCONBRIDGE_UA:C271A
LOC:  GARAGE
MET:  FRONTAL PASSAGE BRISK N WINDS
ELEV:        300.0 m.                  GND TEMP:  10.3 deg.C (GND=7°C)
BASE:        120.0 m.                  BEARING : 134.0 deg.
```

FIGURE 64



MEASURED EXCEEDENCES

JUNE 28, 1983

1/2 Hr. Standard:

Site 1	(MAMU 1)	910-940	.41 ppm
Site 1	(MAMU 1)	940-1010	.34 ppm
Site 1	(MAMU 1)	1010-1040	.47 ppm
Site 1	(MAMU 1)	1040-1110	.40 ppm
Site 1	(MAMU 1)	1110-1140	.39 ppm
Site 1	(MAMU 2)	1300-1330	.87 ppm

1 Hr. Criterion:

Site 1	(MAMU 1)	855-955	.30 ppm
Site 1	(MAMU 1)	955-1055	.45 ppm
Site 1	(MAMU 1)	1055-1155	.37 ppm
Site 1	(MAMU 2)	1230-1330	.55 ppm

SYMBOLS:

○ SO_2 monitors (fixed or mobile)

▲ Falconbridge

▽ Met. stations (including MTC garage)

● Air quality monitor, recording exceedence 1/2 std. or 1 hr. criterion

▼ Air quality monitor & meteorological data acquisition site recording exceedence

FIGURE 65

FALCONBRIDGE: D282

Start: 83/06/28 06:03 Scan: 60 sec. Ave: 30.00 min.
Loc: Hodge & Bennett Streets - Falconbridge (5143-51576)

.010	.018	.028	.038	.035	.054	.062	.073	.077	.083	.090	.094	.097	.108	.100	.104	SRAD	W/cm^2
12	12	13	14	15	15	16	17	18	18	19	19	19	20	20	20	TEMP	d C
78	76	75	73	67	63	61	53	48	45	44	44	45	44	44	42	HUM	%-rel
1018	1018	1018	1018	1018	1018	1018	1018	1018	1018	1018	1018	1017	1017	1017	1017	BAR	mbar-msl

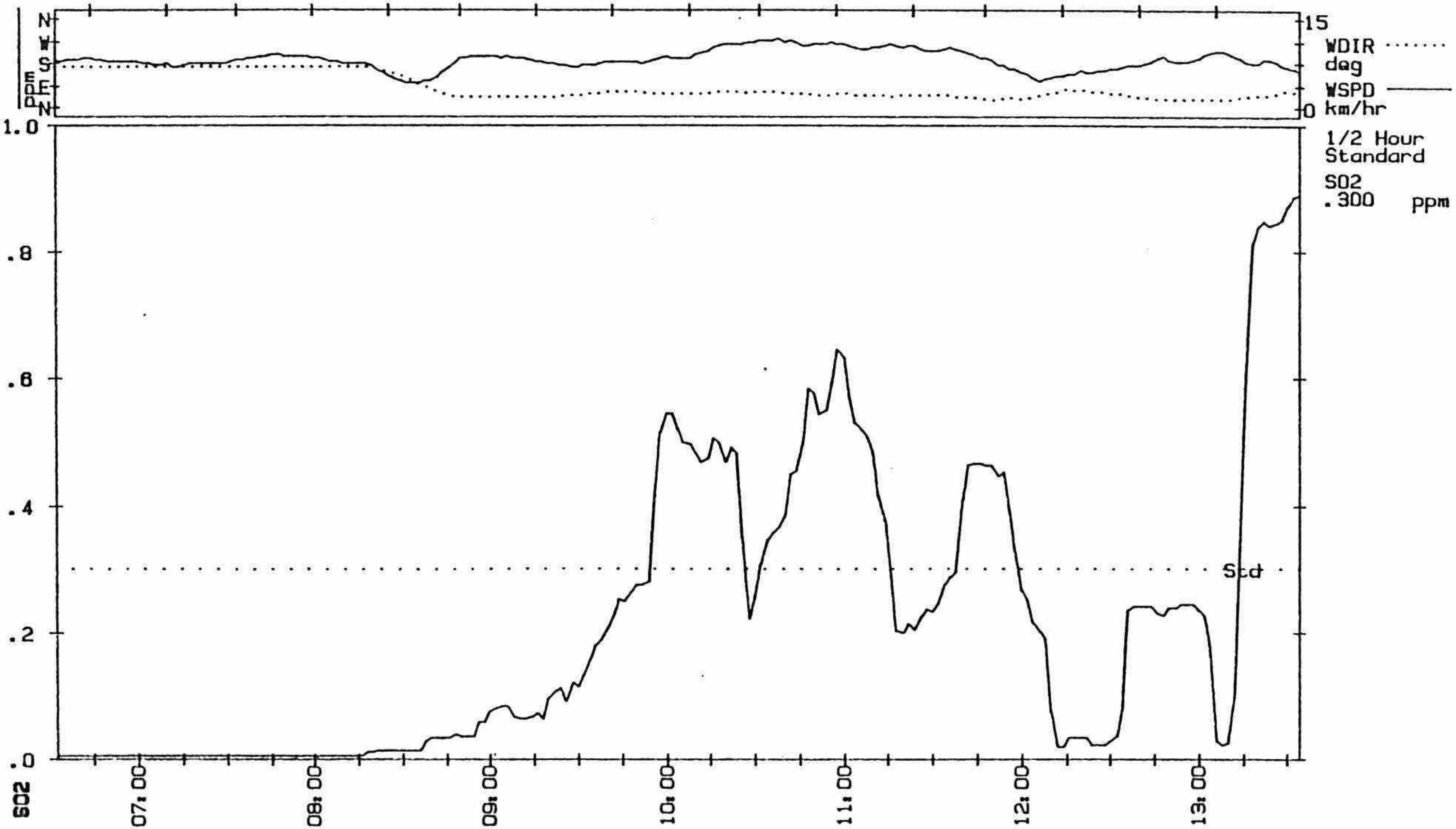
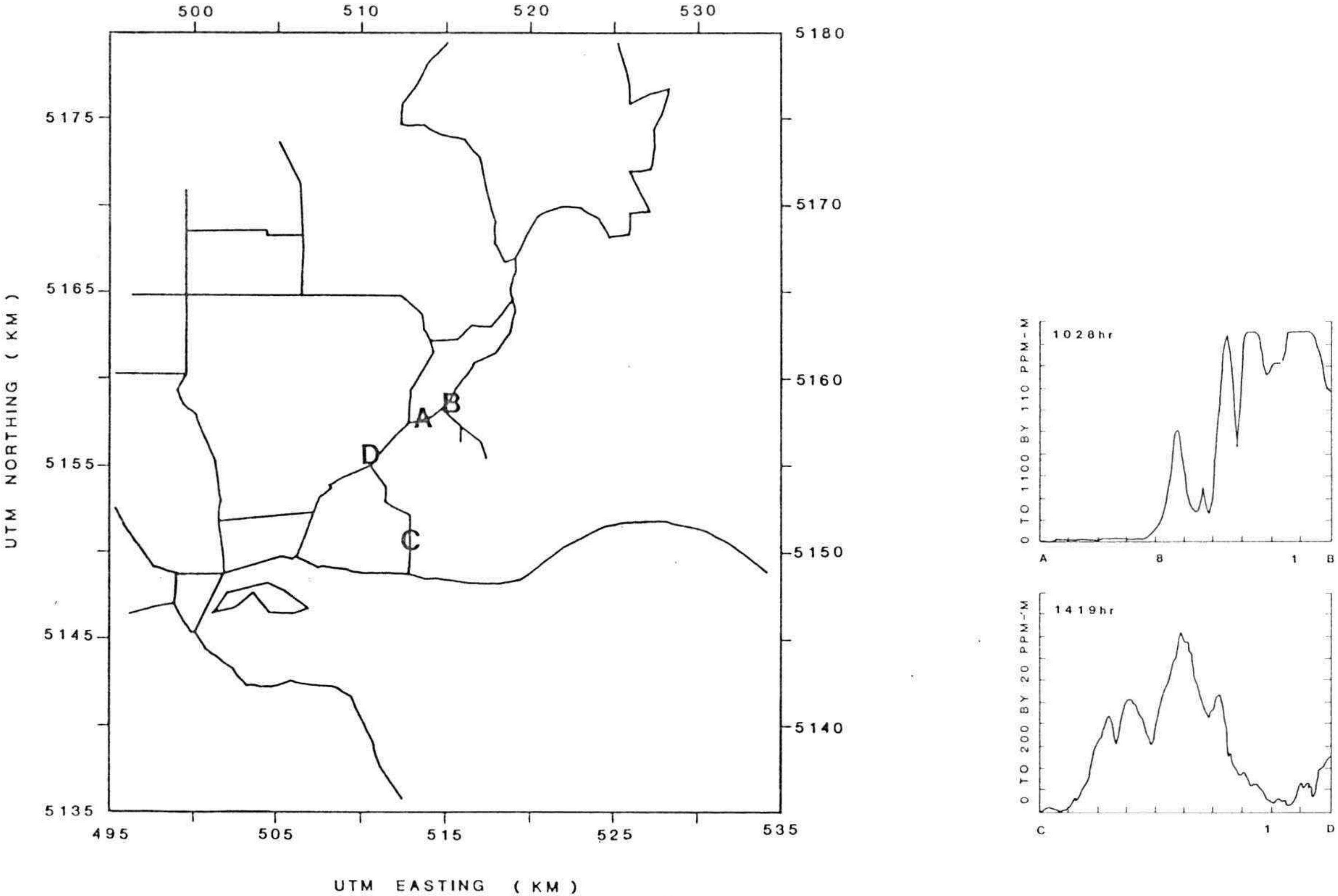
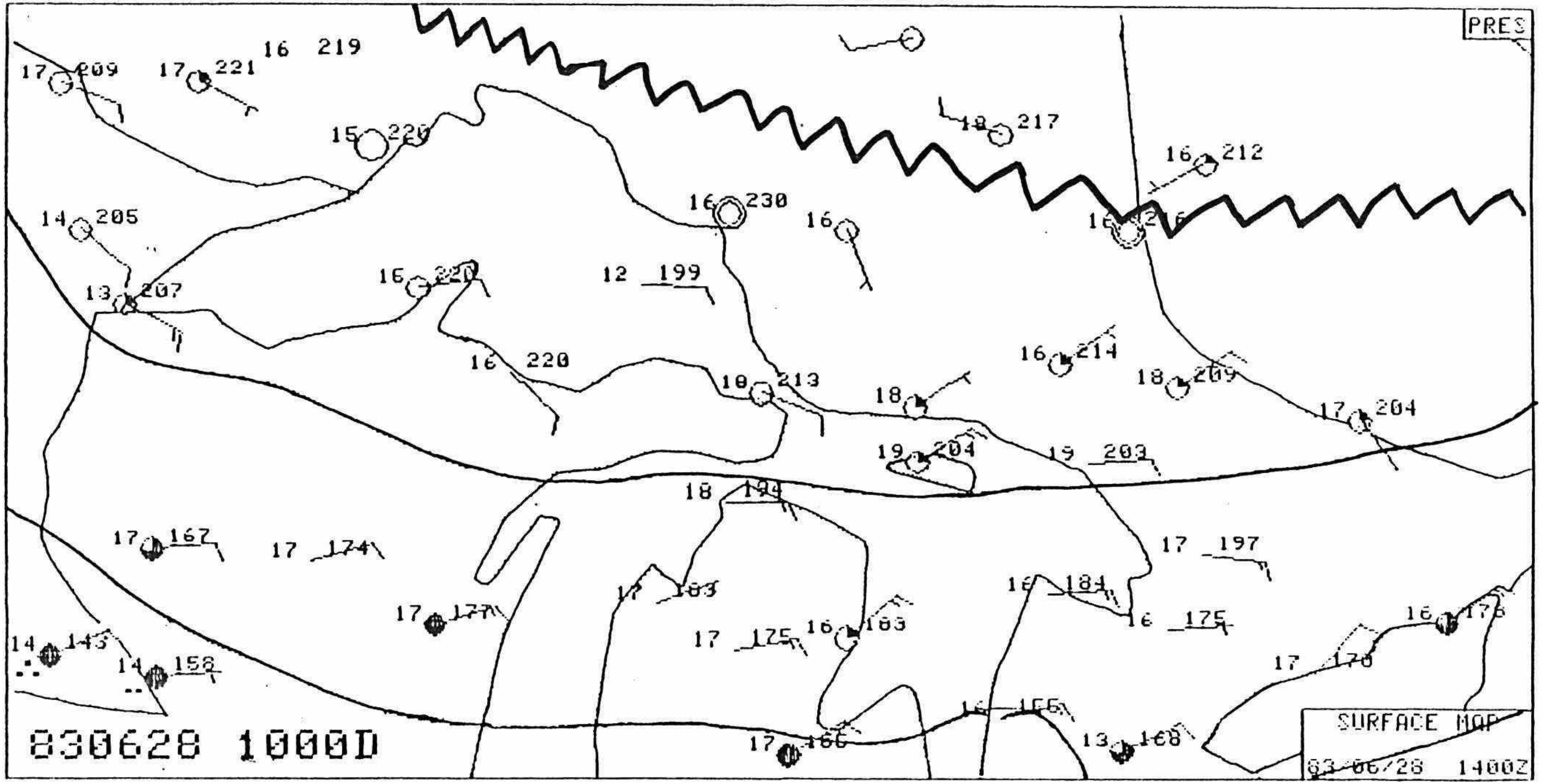


FIGURE 66



FALCONBRIDGE 1983 AMBIENT AIR SURVEY - COSPEC RESULTS - June 28

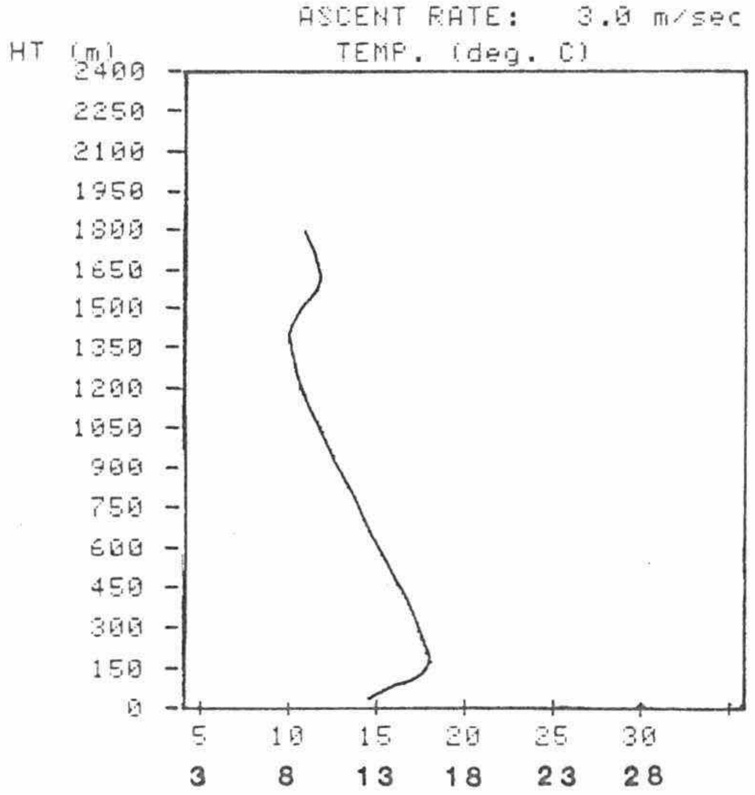
FIGURE 67



SURFACE WEATHER MAP AT 1400Z, JUNE 28, 1983.

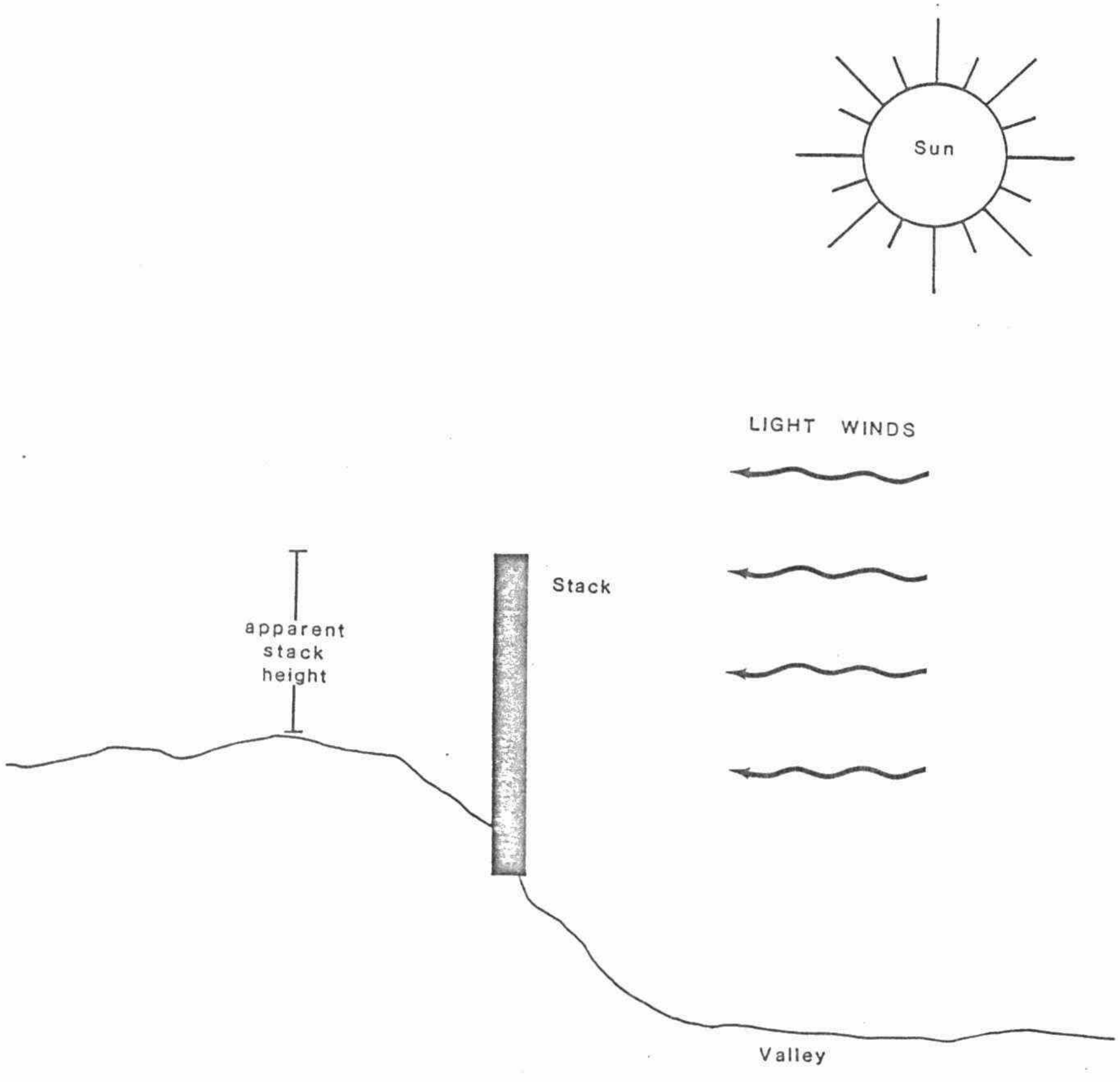
FIGURE 68

TEMPERATURE PROFILE WITH HEIGHT, JUNE 28, 1983.



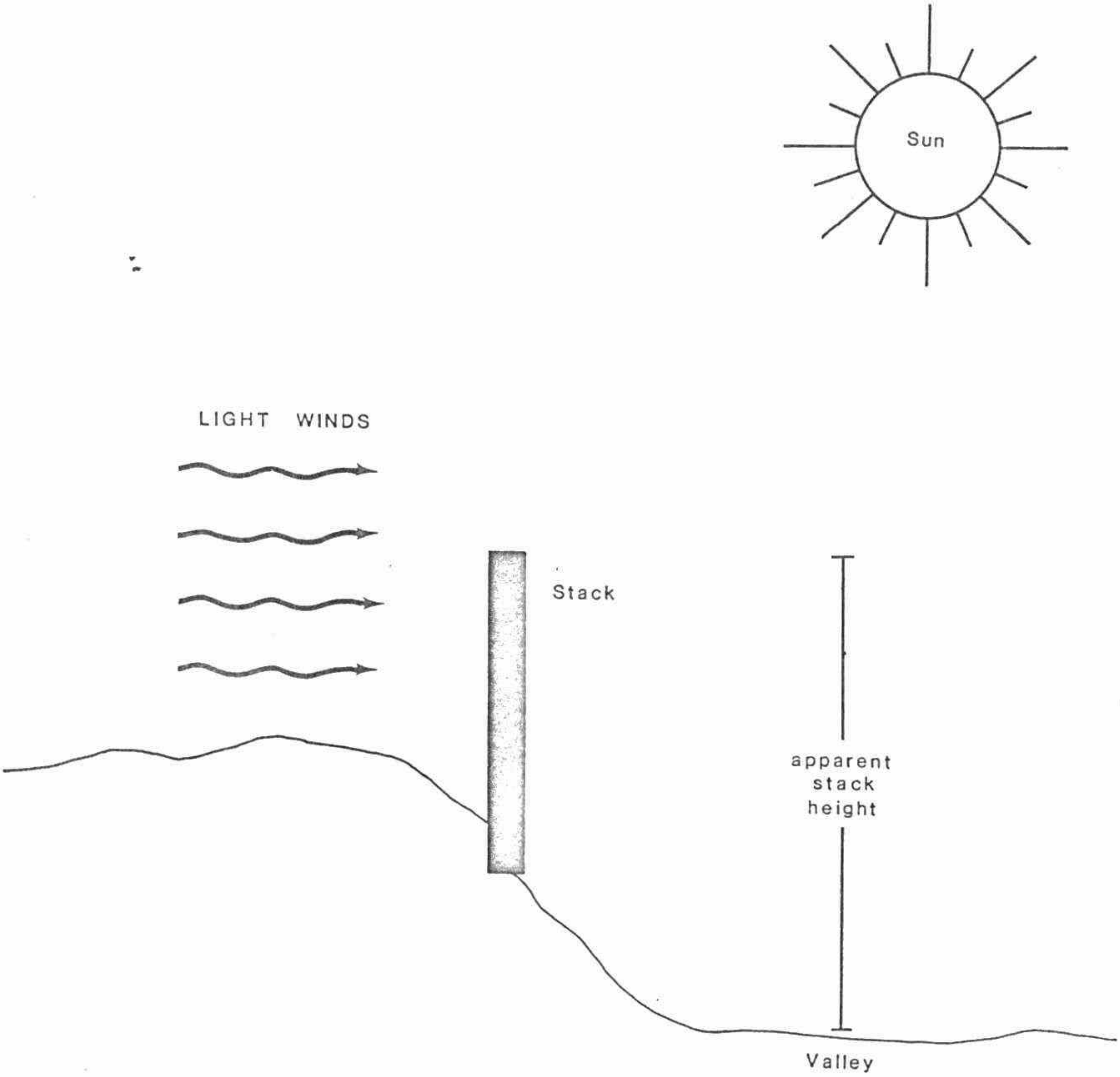
```
NAME: FALCONBRIDGE_UA:C281A
LOC:  GARAGE
MET:  CLEAR COOL NOCTURNAL INVERSION
ELEV:       300.0 m.
BASE:        90.0 m.                    GND TEMP:  11.6 deg.C(10°C )
                                        BEARING : 314.0 deg.
```

FIGURE 69



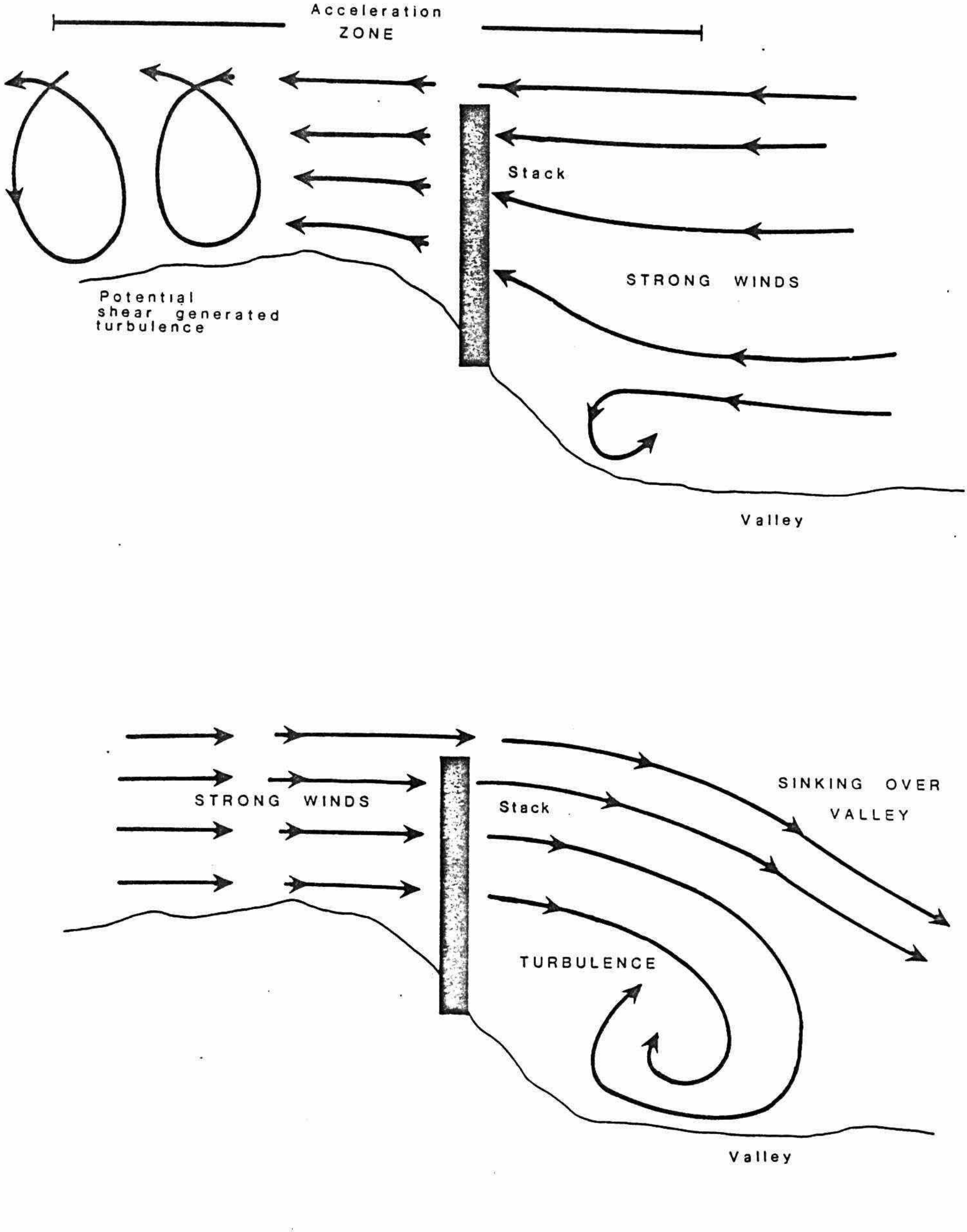
APPARENT STACK HEIGHT TO WEST OF STACK IN LIGHT WINDS.

FIGURE 70



APPARENT STACK HEIGHT TO EAST OF STACK IN LIGHT WINDS.

FIGURE 71



DEPENDENCE OF LOCAL WIND PATTERNS ON WIND DIRECTION.

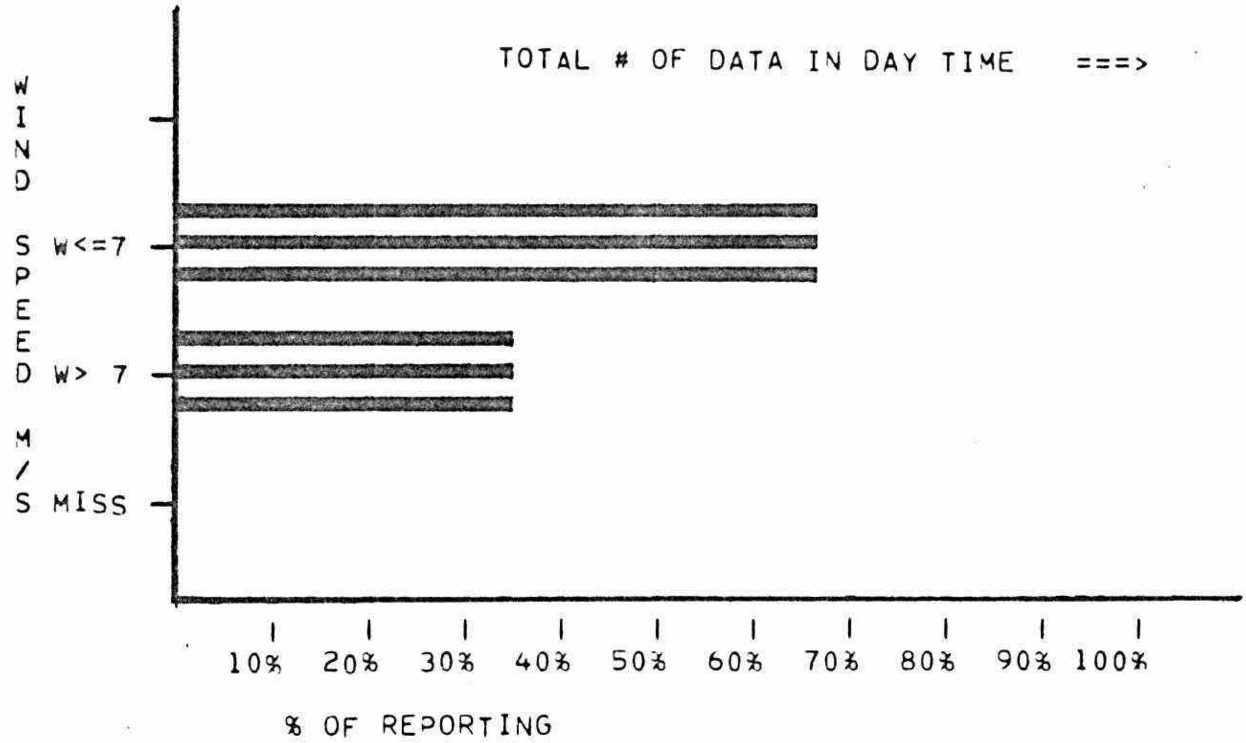
FIGURE 72

SKEAD

TOTAL # OF DATA ===> 226.

HISTOGRAM OF SO2 CONC FOR SO2 > 25 PPHM
FOR 5 YEARS(JULY,78-82)

SUMMER DAY TIME


TOTAL # OF DATA IN DAY TIME ===> 82.

SUMMER DAY TIME

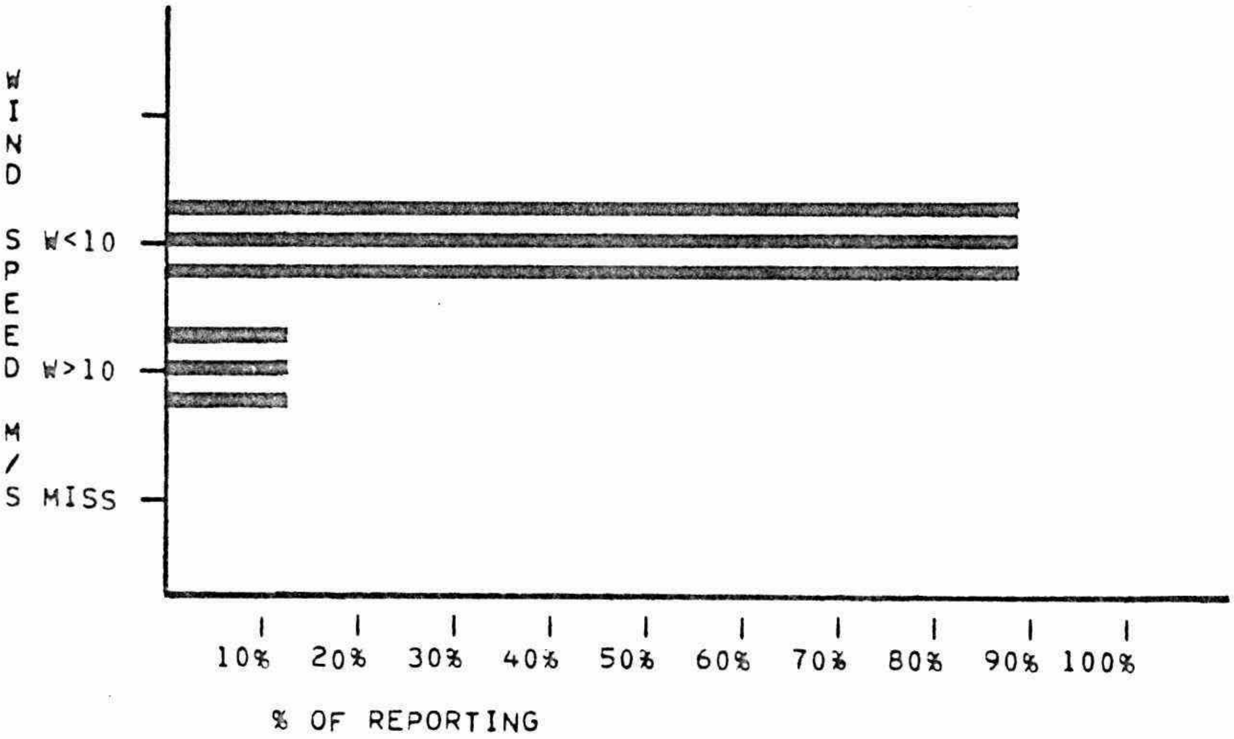
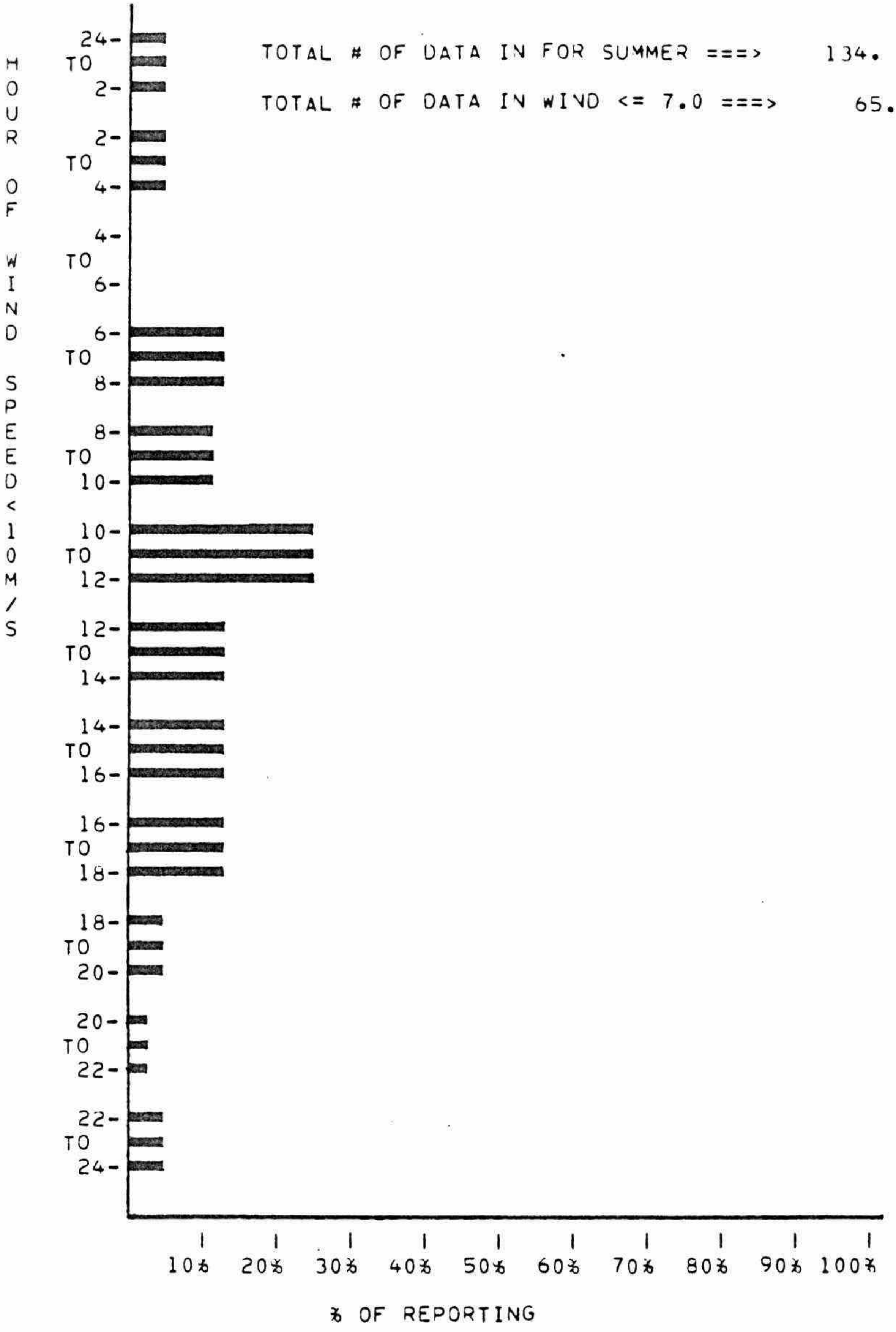


FIGURE 73

SKEAD

HISTOGRAM OF SO2 CONC FOR

WIND SPEED <= 7.0



TOTAL # OF DATA IN FOR SUMMER ===> 134.

TOTAL # OF DATA IN WIND <= 7.0 ===> 65.

FIGURE 74

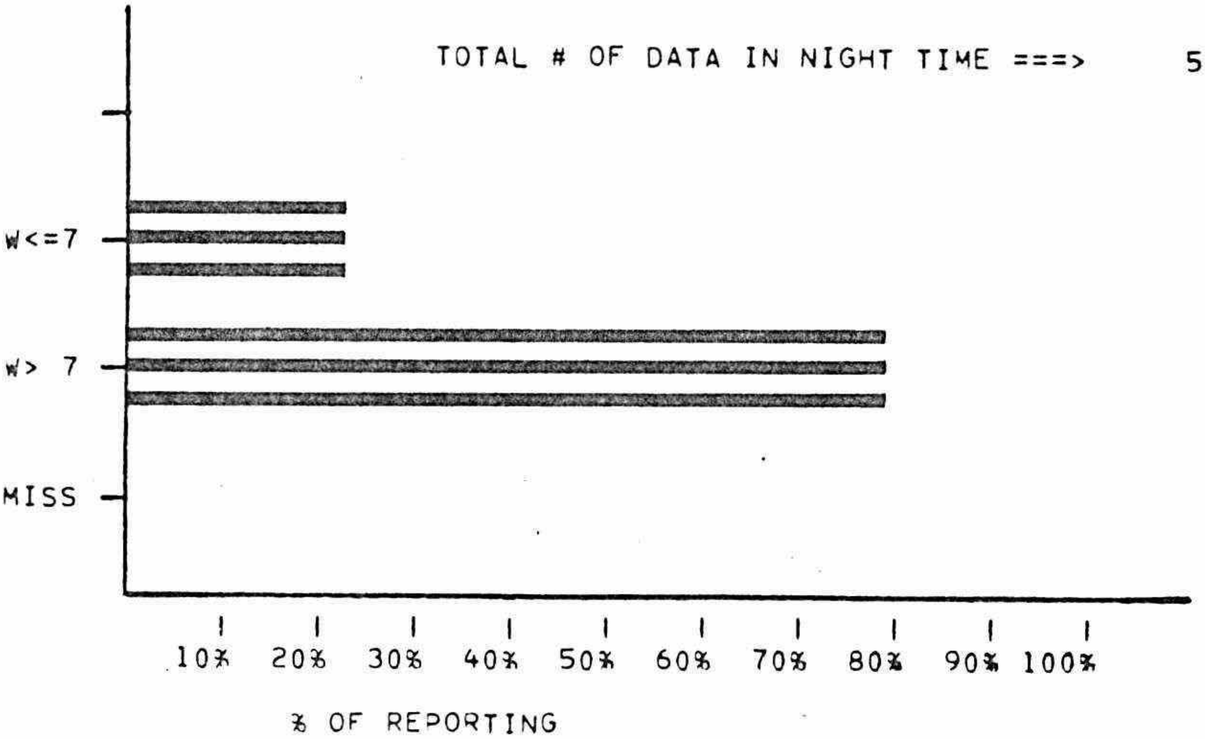
SKEAD

TOTAL # OF DATA ===> 226.

HISTOGRAM OF SO2 CONC FOR SO2 > 25 PPHM

FOR 5 YEARS(JULY,78-82)

SUMMER NIGHT TIME



WINTER TIME

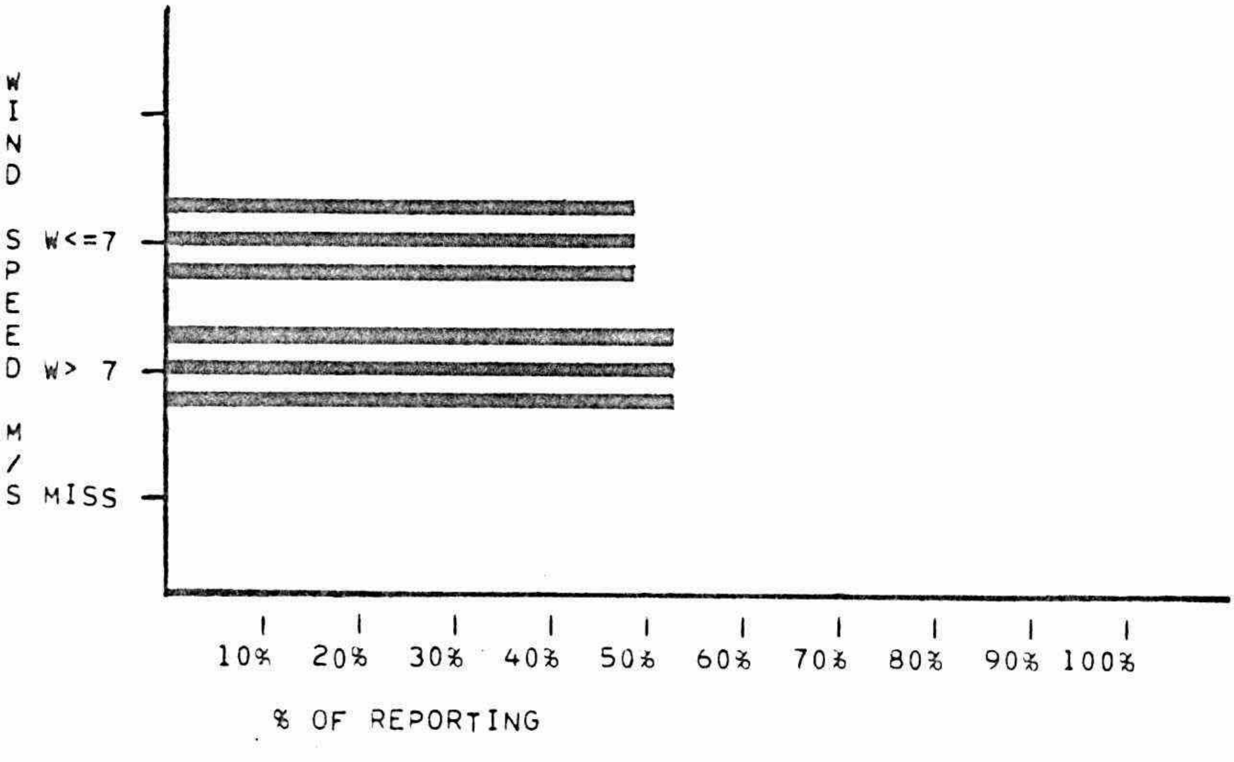


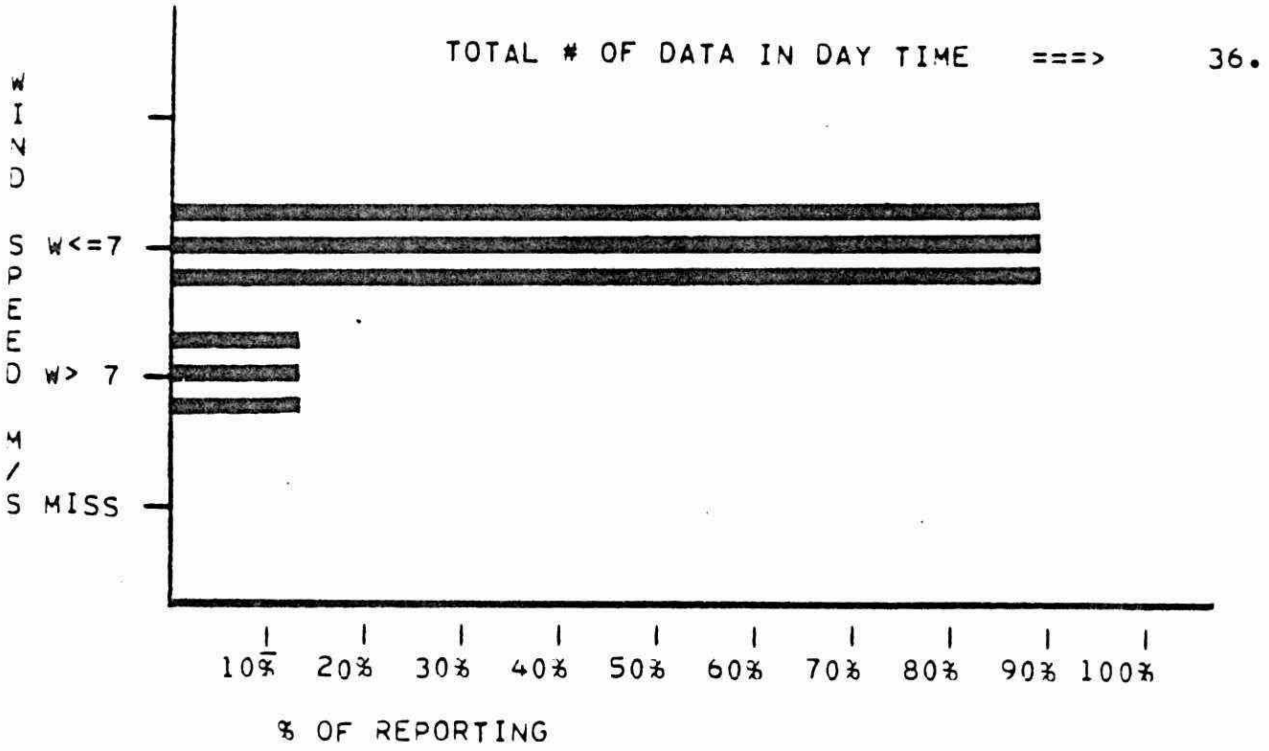
FIGURE 75

CONISTON

TOTAL # OF DATA ===> 75.

HISTOGRAM OF SO2 CONC FOR SO2 > 25 PPHM
FOR 6 YEARS(JULY,78-83)

SUMMER DAY TIME



SUMMER DAY TIME

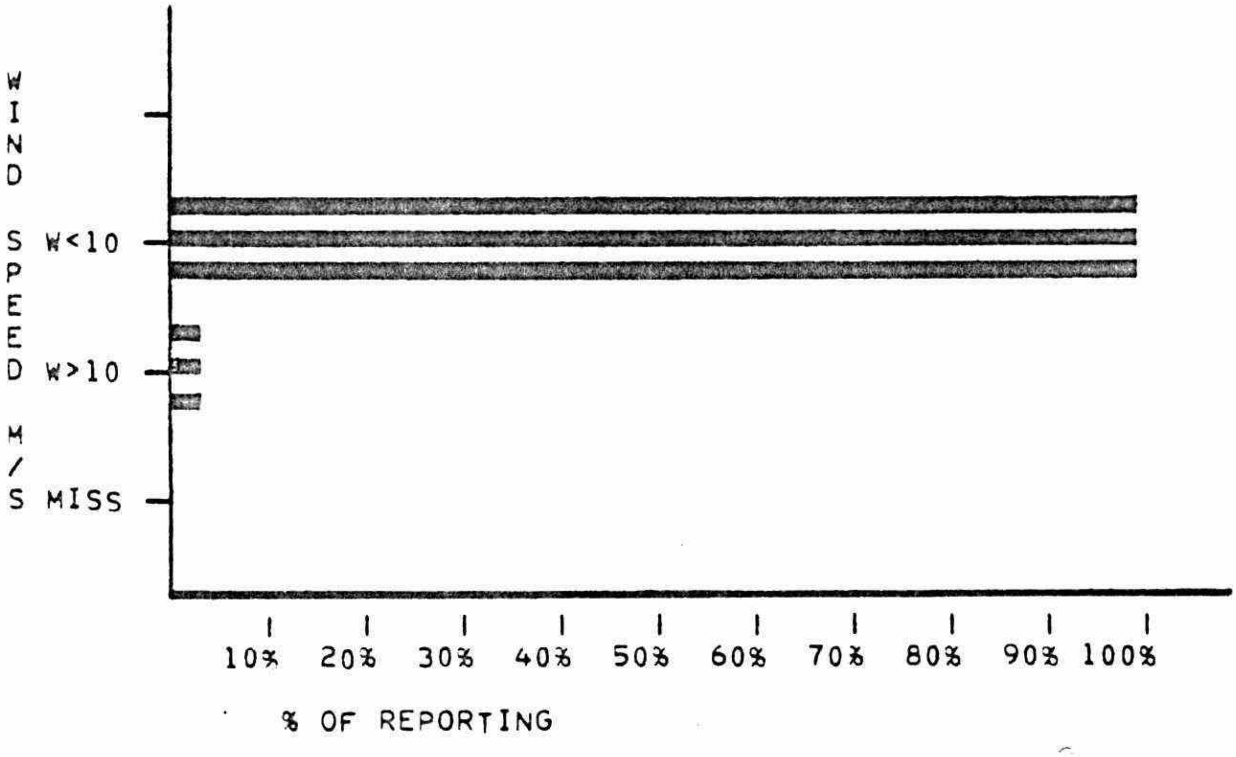
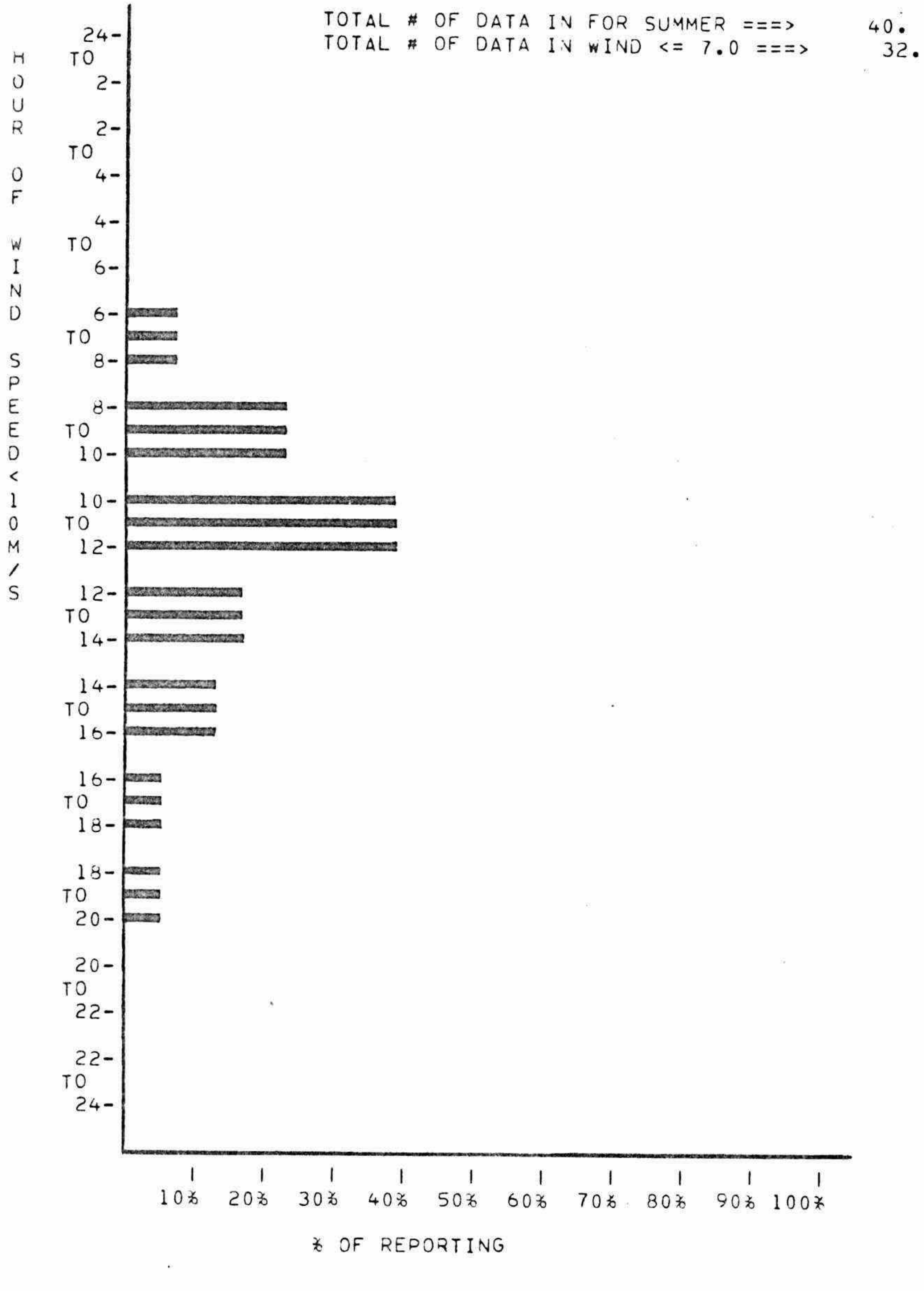


FIGURE 76

CONISTON

HISTOGRAM OF SO2 CONC FOR

WIND SPEED <= 7.0



TOTAL # OF DATA IN FOR SUMMER ===> 40.
TOTAL # OF DATA IN WIND <= 7.0 ===> 32.

FIGURE 77A

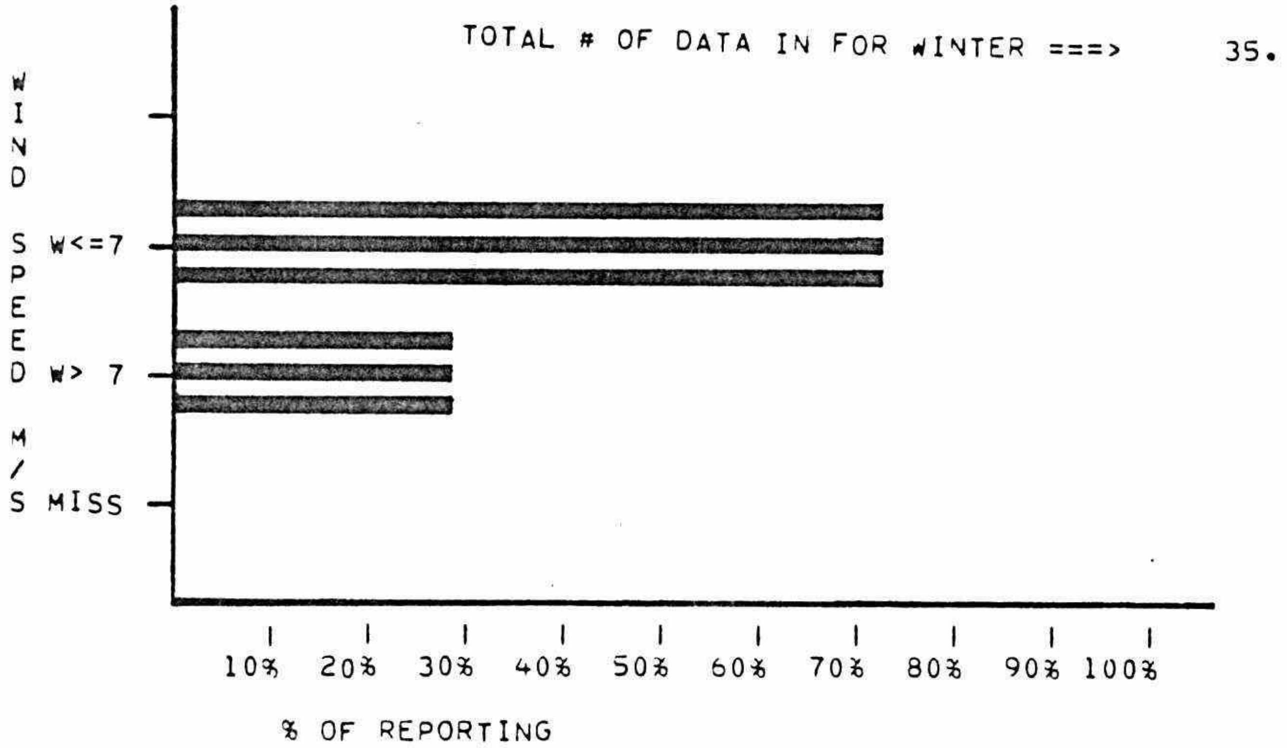
CONISTON

TOTAL # OF DATA ===> 75.

HISTOGRAM OF SO2 CONC FOR SO2 > 25 PPHM

FOR 6 YEARS(JULY,78-83)

WINTER TIME



SUMMER TIME

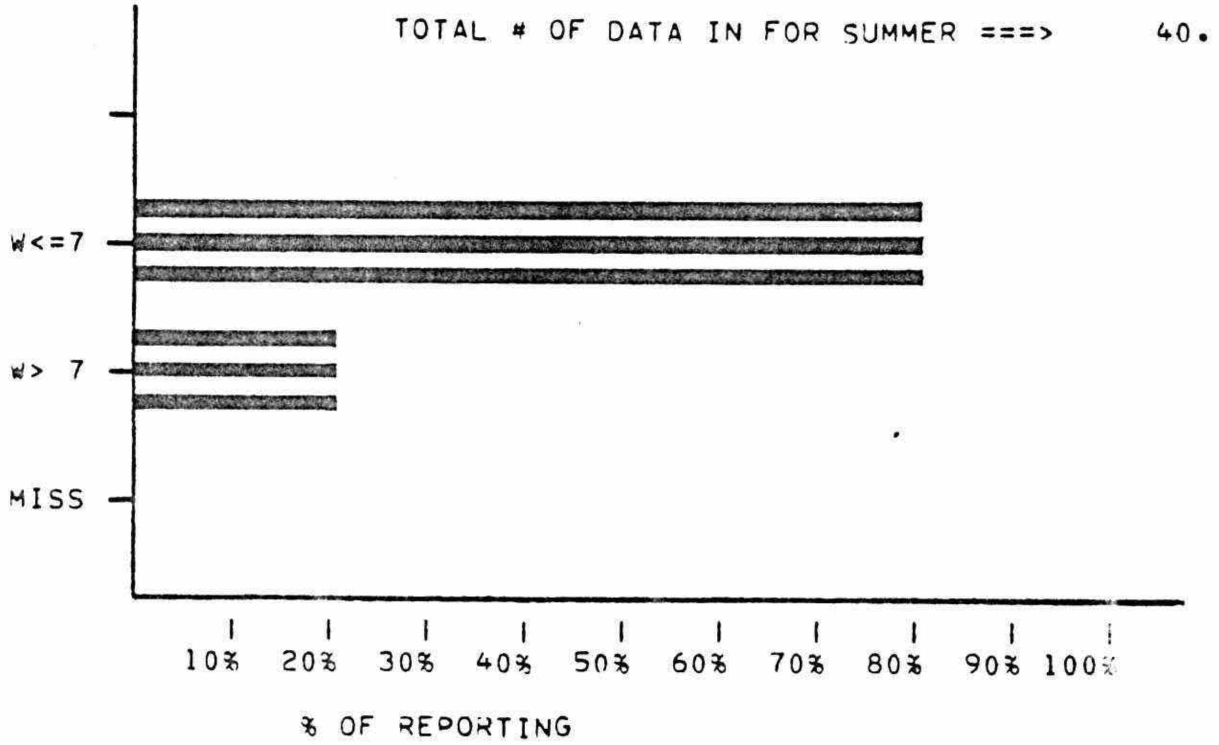


FIGURE 77B

CONISTON

HISTOGRAM OF SO2 CONC FOR

WIND SPEED <= 7.0

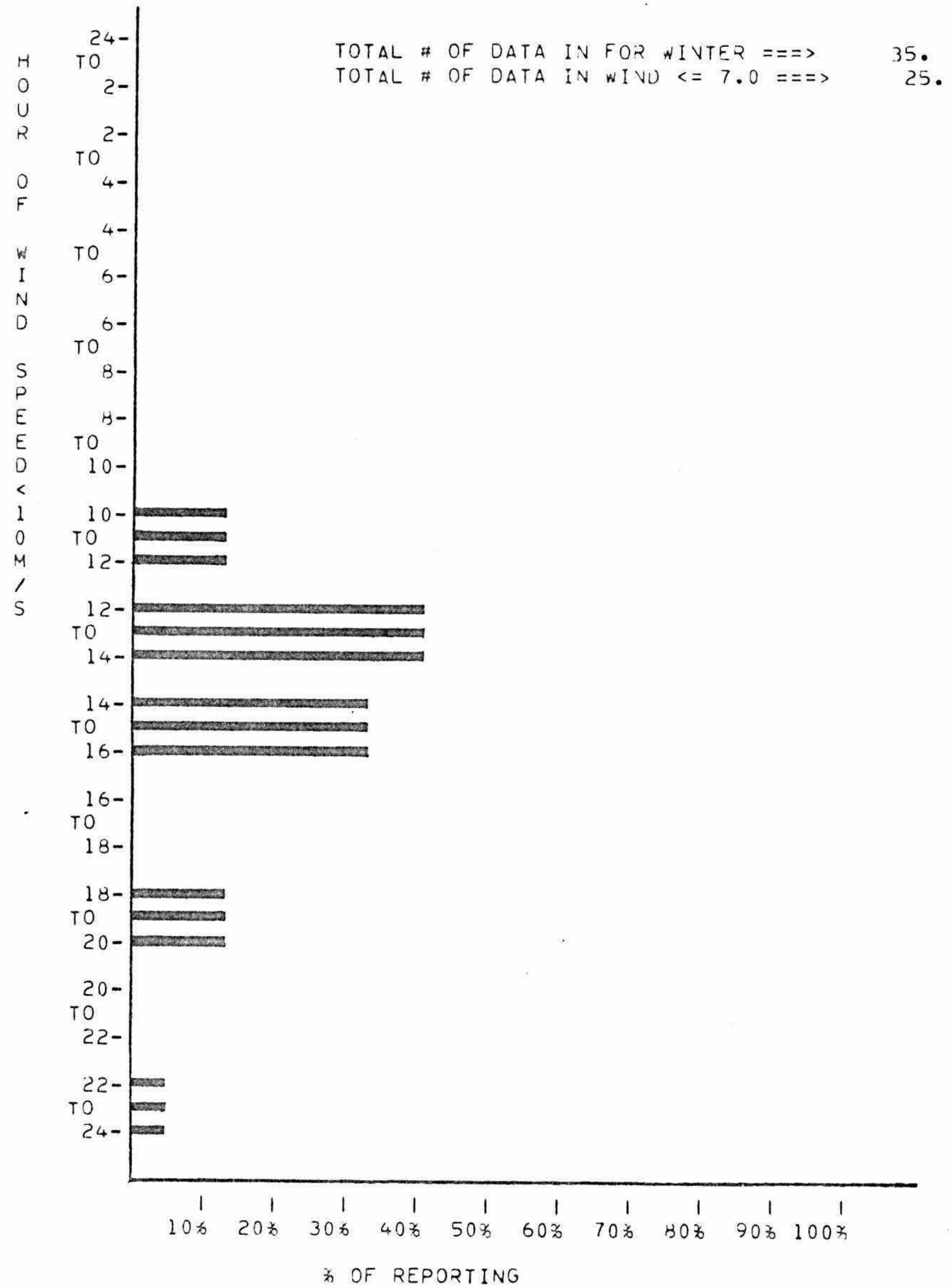


FIGURE 78

EXCEEDENCE CASE STUDY

DATE: 83/05/11 - 83/06/28

LINEAR ANALYSIS:

R * R = 0.5732

A = -0.10 , B = 1.83

T = 30.9150 , SE = 0.0225

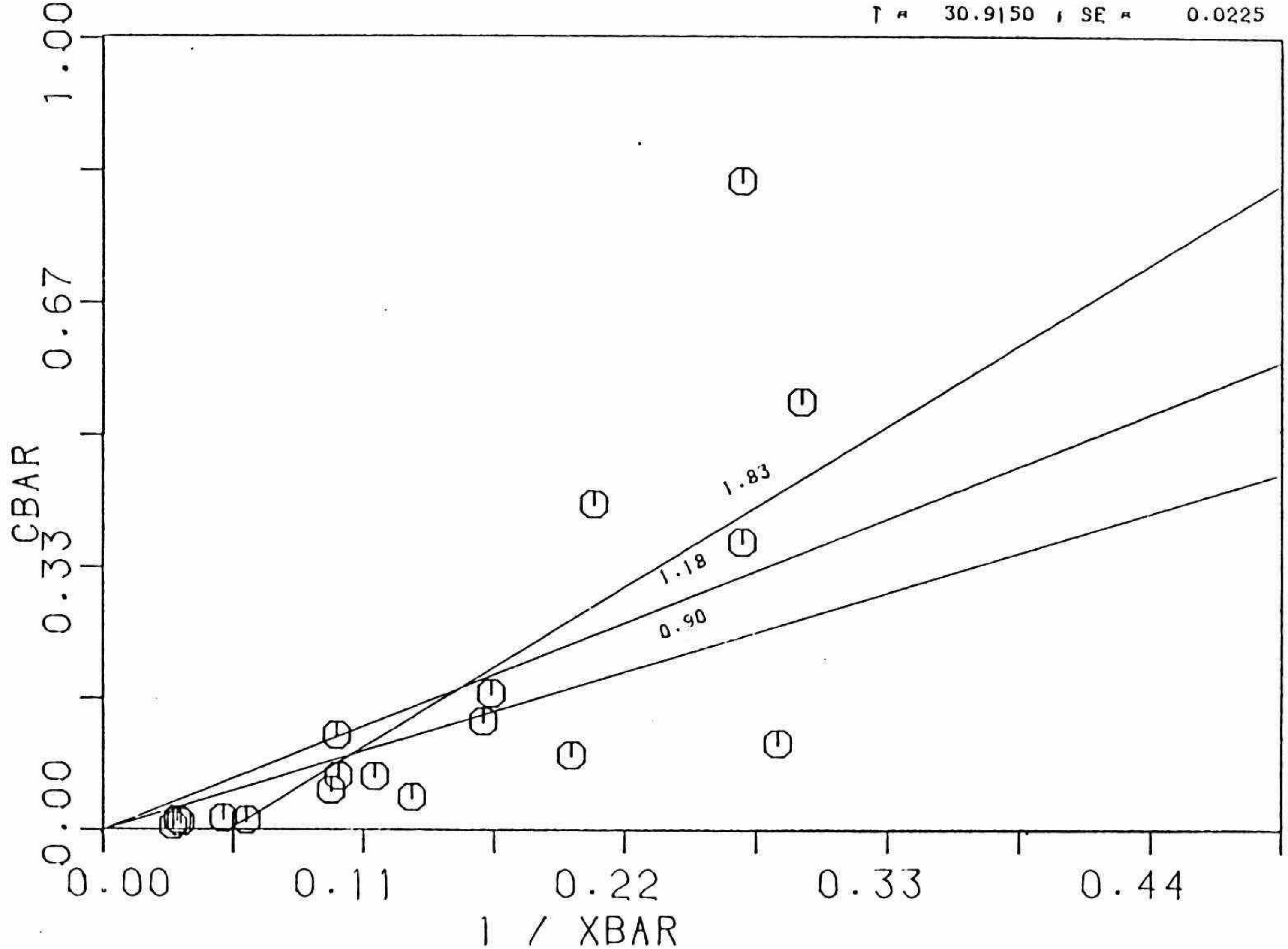
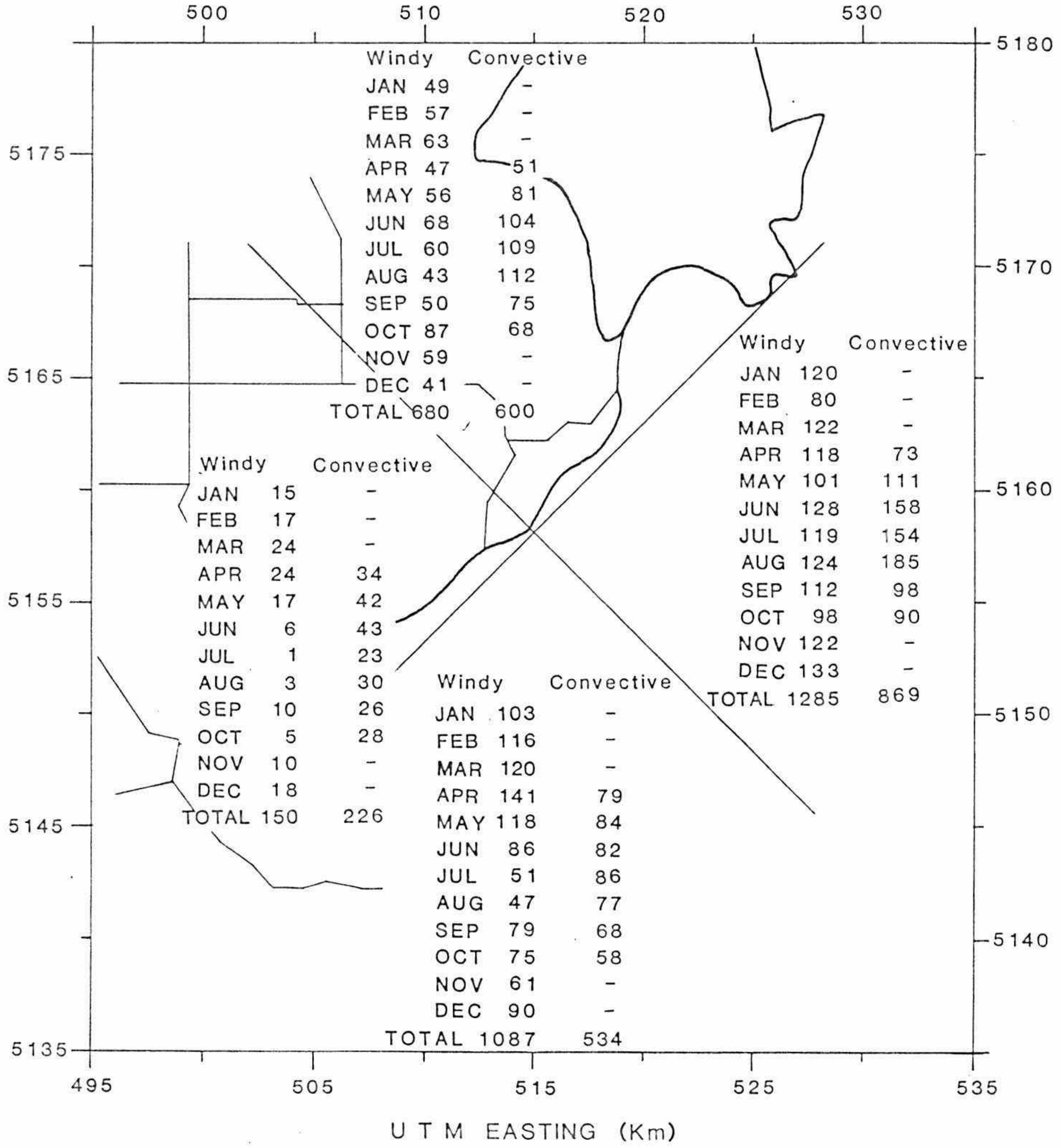


FIGURE 79



	Windy	Convective
JAN	49	-
FEB	57	-
MAR	63	-
APR	47	51
MAY	56	81
JUN	68	104
JUL	60	109
AUG	43	112
SEP	50	75
OCT	87	68
NOV	59	-
DEC	41	-
TOTAL	680	600

	Windy	Convective
JAN	15	-
FEB	17	-
MAR	24	-
APR	24	34
MAY	17	42
JUN	6	43
JUL	1	23
AUG	3	30
SEP	10	26
OCT	5	28
NOV	10	-
DEC	18	-
TOTAL	150	226

	Windy	Convective
JAN	120	-
FEB	80	-
MAR	122	-
APR	118	73
MAY	101	111
JUN	128	158
JUL	119	154
AUG	124	185
SEP	112	98
OCT	98	90
NOV	122	-
DEC	133	-
TOTAL	1285	869

	Windy	Convective
JAN	103	-
FEB	116	-
MAR	120	-
APR	141	79
MAY	118	84
JUN	86	82
JUL	51	86
AUG	47	77
SEP	79	68
OCT	75	58
NOV	61	-
DEC	90	-
TOTAL	1087	534

AVERAGE NUMBER OF HOURS WINDS INTO EACH QUADRANT ARE ESTIMATED TO HAVE BEEN GREATER THAN 7m s^{-1}(WINDY CASE) OR NUMBER OF HOURS OF LIGHT WINDS DURING POTENTIALLY CONVECTIVE PERIODS. BASED ON METEOROLOGICAL DATA FROM 1975 THROUGH 1983.

TD
883 7
O6
I49
1981